CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Evaluation of Agriculturally Dominated Water Bodies in Relation to Municipal and Domestic Supply (MUN) Beneficial Use

Sacramento Valley Archetypes

Final Report

December 2014*

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

*California Department of Public Health (DPH) was changed to the State Water Resources Control Board's Division of Drinking Water (DDW) to reflect current programs in the main report and Appendix F on March 16, 2015.

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ACKNOWLEDGEMENTS:

This report was made possible through hours of field and lab work, quality assurance, data compilation and data analysis, primarily performed by staff of the AG Regulatory Planning Unit and Scientific Aids of the California State Surface Water Ambient Monitoring Program (SWAMP). Additional resources were provided through the Central Valley Salinity Alternatives Long-Term Sustainability (CV-SALTS) initiative, Irrigated Lands Regulatory Program (ILRP) coalitions, local Publicly Operated Treatment Works (POTWs), and other local, state, and federal stakeholders including the water agencies that are currently managing and maintaining the water bodies in question.

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1.0 EXECUTIVE SUMMARY

From April 2012 through September 2013, staff from the Central Valley Regional Water Quality Control Board (Central Valley Water Board) conducted an evaluation of water bodies upstream and downstream of Publicly Owned Treatment Works (POTW) discharges from the cities of Colusa, Willows, Live Oak, and Biggs in the Sacramento River Basin to determine whether conditions could reasonably be expected to support the municipal and domestic supply (MUN) beneficial use. Characterization of the water bodies included an evaluation of whether the water body was a natural, modified or constructed channel (based on local water agency records) in addition to spatial and temporal water quality analyses.

To leverage resources, provide access, and insure transparency, the project was coordinated with the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) initiative, Irrigated Lands Regulatory Program (ILRP) coalitions, local POTWs, and other local, state and federal stakeholders including the water agencies that are currently managing and maintaining the water bodies in question.

Land uses within the four POTW's areas are mainly agriculture (Ag). Based on records available from the water agencies currently managing the water bodies in question, all of the water bodies were either constructed or modified to convey Ag drainage. There was no evidence of water being diverted nor permitted for MUN. Almost all of the water bodies evaluated were surrounded by rice fields.

Nineteen water bodies totaling approximately 300 miles were sampled for this study and included: Sutter Bypass, Wadsworth Canal, Colusa Basin Drain, Powell Slough, Butte Slough, Unnamed Tributary, New Ditch, Lateral Drain #2, Main Drainage Canal, Cherokee Canal, Hunter Creek, Logan Creek, Lateral K, Willow Creek, Ag Drain C, and Butte Creek. These water bodies either represented background conditions or received effluent from the cities of Colusa, Willows, Live Oak, and/or Biggs. All of the water bodies except for the Colusa Basin Drain and Sutter Bypass are currently designated with the MUN beneficial use under the statewide Sources of Drinking Water Policy (88-63).

Water quality sampling in the water bodies occurred from April 2012 through September 2013, primarily Water Year 2013. Water Year 2013 was classified a dry year based on the Sacramento Valley Water Year Type Index and followed a dry year in water year 2012 and a wet year in water year 2011.

Sampling within each POTW study area was conducted twice a month from April 2012 through March 2013 period. Sampling frequency was then reduced to once a month from April 2013 through September 2013 due to limited staff resources. Constituents identified through the POTW's NPDES permit renewal process at concentrations that may exceed the evaluation criteria for protecting drinking water supplies were analyzed. In June 2012, additional constituents specified in provisions of Title 22 of the California Code of Regulations to protect human health and human health-based standards in the California Toxics Rule (CTR) were analyzed. *E. coli* analyses were conducted monthly from August 2012 to September 2013. In total, 226 different constituents were evaluated during the course of the study.

All constituents were evaluated against Maximum Contaminant Levels (MCLs) specified in provisions of Title 22 of the California Code of Regulations, the California Toxics Rule (CTR) criteria, and other numeric water quality criteria listed in Appendix F for constituents without a MCL or CTR criteria to determine whether water quality may be suitable for MUN and protection of human health.

Based on the overall characterization of the water bodies receiving effluent from the cities of Colusa, Willows, Live Oak, and Biggs:

- Source water to the area is primarily stormwater runoff and wetland drainage during the winter and diversion of Sacramento and Feather River water, ground water, and agricultural and wetland drainage during the summer;

- All diversion and water rights within the water bodies are for irrigation use;

- All of the water bodies evaluated were specifically constructed or modified to convey agricultural drainage to facilitate agricultural operations throughout the basin;

- Flow patterns are dependent on local agricultural practices, can vary greatly throughout the year and would likely be dry during extended periods without surrounding irrigation practices;

- When analyzing the water quality results collected from the four study areas against 144 criteria to protect MUN and/or human health, most constituents were below the evaluation criteria and for those that were above the criteria, some elevated concentrations occurred in the effluent but the majority occurred upstream and/or downstream of where the effluent might influence water quality.

- The following constituents showed a pattern of consistently elevated levels throughout the overall study area: SC; TDS; nitrate as nitrogen; total aluminum; iron; manganese; and sodium;

    - Total aluminum, iron, and manganese were found at elevated levels at all sites upstream and downstream of the influence of the effluent;
        - The dissolved forms of these constituents did not exceed criteria;

    - SC, TDS, and nitrate as nitrogen were elevated in the effluent, but concentrations dissipated after the first downstream site;

    - Sodium exceeded criteria at all sites samples—effluent and water bodies;

- Total and dissolved arsenic were elevated in the Colusa and Live Oak study areas (the southern portion of the overall study area):

- Trihalomethanes were consistently reported at elevated levels in the City of Willow’s effluent but not in any of the upstream or downstream sites except for two detections of chloroform upstream of the effluent in the northern portion of the basin;

- *E. coli* concentrations were randomly elevated above its criteria in both upstream and downstream of the influence from the cities' effluents; and

- Constituents with elevated levels not related to the effluent appear to be linked to elevated levels in local ground water (e.g. arsenic) while others such as aluminum, iron and manganese have correlate to historical background concentrations of metals in the surface waters of the Sacramento River Basin.

2.0 GLOSSARY/KEY TERMS

Ag – Agricultural

Basin Plans – Central Valley Regional Water Quality Control Board Basin Plans

PHG – California Public Health Goals

Central Valley Water Board – Central Valley Regional Water Quality Control Board

CDPH – California Department of Public Health

CTR – California Toxics Rule

CV-SALTS – Central Valley Salinity Alternatives Long-Term Sustainability

DDW – Division of Drinking Water

DO – Dissolved Oxygen

DWR – Department of Water Resources

E. coli – Escherichia coli

GAMA – Groundwater Ambient Monitoring and Assessment

ILRP – Irrigated Lands Regulatory Program

MBAS – Methylene Blue Active Substances

MCL – Maximum Contaminant Level

MDL – Method Detection Limit

MPN – Most Probable Number

MUN – Municipal and Domestic Supply

NPDES – National Pollutant Discharge Elimination System

PCBs – Polychlorinated Biphenyls

POTW – Publicly Owned Treatment Works

QA – Quality Assurance

QAPP – Quality Assurance Project Plan

QC – Quality Control

RPA – Reasonable Potential Analyses

RL – Reporting Limit

SC – Specific Conductance

State Water Board – State Water Resources Control Board

SWAMP – Surface Water Ambient Monitoring Program

TDS – Total Dissolved Solids

THMs – Trihalomethanes

USEPA – U.S. Environmental Protection Agency

VOA – Volatile Organic Analysis

VOC – Volatile Organic Compound

WWTP – Waste Water Treatment Plant

YSI – Yellow Springs Instruments

3.0 INTRODUCTION

In response to the statewide Sources of Drinking Water Policy (88-63), the Central Valley Regional Water Quality Control Board's Water Quality Control Plans for the Sacramento and San Joaquin River Basins and the Tulare Lake Basin (Basin Plans) designate the Municipal and Domestic Supply (MUN) beneficial use to all water bodies unless they are specifically listed as water bodies that are not designated with MUN. The Basin Plans state that water bodies designated for the MUN must not exceed the Maximum Contaminant Levels (MCLs) for chemical constituents, pesticides, and radionuclides specified in Title 22 of the California Code of Regulation. While 88-63 does contain exceptions for the MUN designation, to utilize the exception, the Basin Plans require ". . . a formal Basin Plan amendment and public hearing, followed by approval of such an amendment by the State Water Board and the Office of Administrative Law." (Central Valley Water Board, 2011).

During Publicly Owned Treatment Works (POTWs) permit adoptions under the National Pollutant Discharge Elimination System (NPDES) program, there have been challenges to protecting the MUN beneficial use designation in agricultural (Ag) drains due to the stated exception for conveyances that transport Ag drainage in 88-63. The cost for POTWs to comply with protecting the MUN beneficial use has been estimated at $3 - $7 million (City of Willows, case example). As part of the permit process, the POTWs have been provided the option of pursuing a basin plan amendment to propose removing MUN designation from the receiving waters.

Concurrently, the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) initiative has identified the protection of MUN beneficial uses in agriculturally dominated water bodies as potentially over restrictive and in need of evaluation in order to facilitate efforts to conserve and recycle water within Ag production areas. CV-SALTS identified receiving waters of four POTWs within the Sacramento River Basin (serving the cities of Colusa, Willows, Live Oak, and Biggs) as potential archetypes for evaluating appropriateness of a MUN designation. These same POTWs have challenged the MUN designation during NPDES permit renewals.

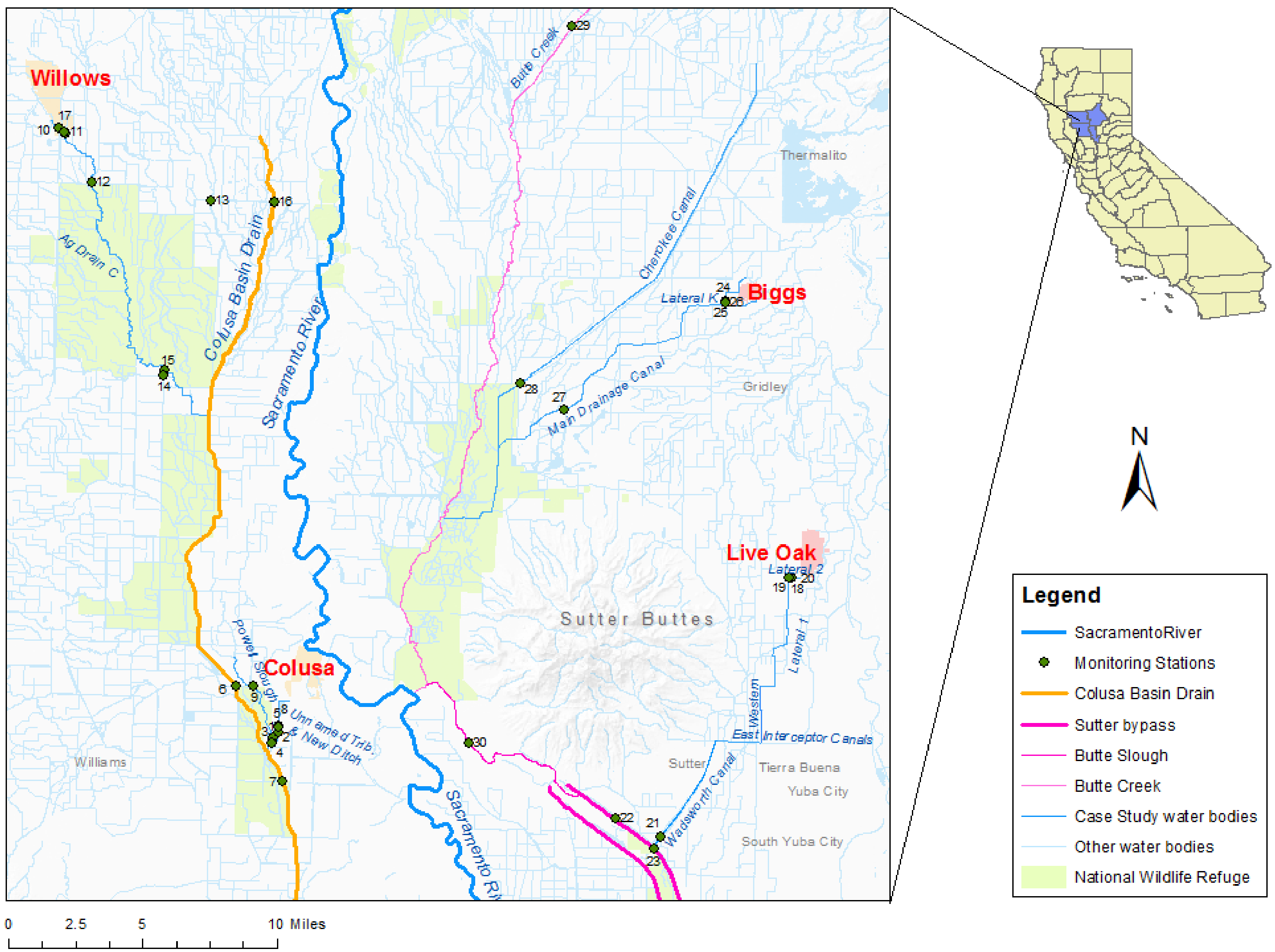
In May 2011, a draft Central Valley Water Board staff report evaluated the appropriateness of the MUN beneficial use in a water body (Ag drain) receiving effluent. The report found that more data needed to be collected before determining if a basin plan amendment was appropriate. The data needs noted included: characterization of the receiving waters, water quality data for the effluent and all receiving waters, flow data for all of the receiving waters, an antidegradation analysis, and an environmental analysis (Central Valley Water Board, 2011).

This report documents a study of the characteristics of the receiving waters for effluent from the cities of Colusa, Willows, Live Oak, and Biggs including purpose and use of the water bodies in question and 18-months of water quality data.

4.0 STUDY AREA

The focus of this report is on the water quality of 19 water bodies receiving effluent from the cities of Colusa, Willows, Live Oak, and Biggs in the Sacramento River Basin. This section focuses on the overall hydrology for the west side and east side of the basin and as well as the four subareas of Colusa, Willows, Live Oak and Biggs. Figure 1 shows a map of the case study area.

Figure 1 Sacramento Case Study Area and Monitoring Stations (see Table 1 for Map Label)



4.1 West Side of the Sacramento River Basin – Colusa Basin Watershed

The Colusa Basin Watershed consists of just over 1 million acres of the Sacramento Valley. The watershed is located between the lower Stoney Creek watershed to the north and the Cache Creek watershed to the south, and is bounded on the east by the Sacramento River and on the west by the crest of the California Coast Ranges. The Colusa Basin is generally a low lying area on the west side of the Sacramento River and east of Interstate 5. The basin stretches from approximately Hamilton City south to Knights Landing. This area is a vast floodplain that has historically been subject to flooding during the rainy season. Transformation of the Colusa Basin into an important Ag region began in the 19th century when settlers moved to the area. In the second half of the 1800s federal and state legislation created projects for flood protection, drainage, and irrigation of the Colusa Basin to encourage agriculture and urbanization. In the early 1900s, the Colusa Basin Drain was constructed to channelize flood water and serve as an Ag drain (Colusa County Resource Conservation District, 2012). The main irrigation water supply for the area is diversion of the Sacramento River at Hamilton City. As water moves through the system, drainage may be recycled into supply channels to maximize use. Beneficial uses of the Colusa Basin Drain are specifically identified in the Basin Plan; MUN is not a designated use of the drain. Virtually every surface water body in the Colusa Basin has either been constructed or modified to be a component of the entire system that provides drainage, irrigation, and flood protection to the basin. This system is the enabling factor that has provided for the existence of the vast Ag industry within the basin.

4.1.1 Colusa Subarea

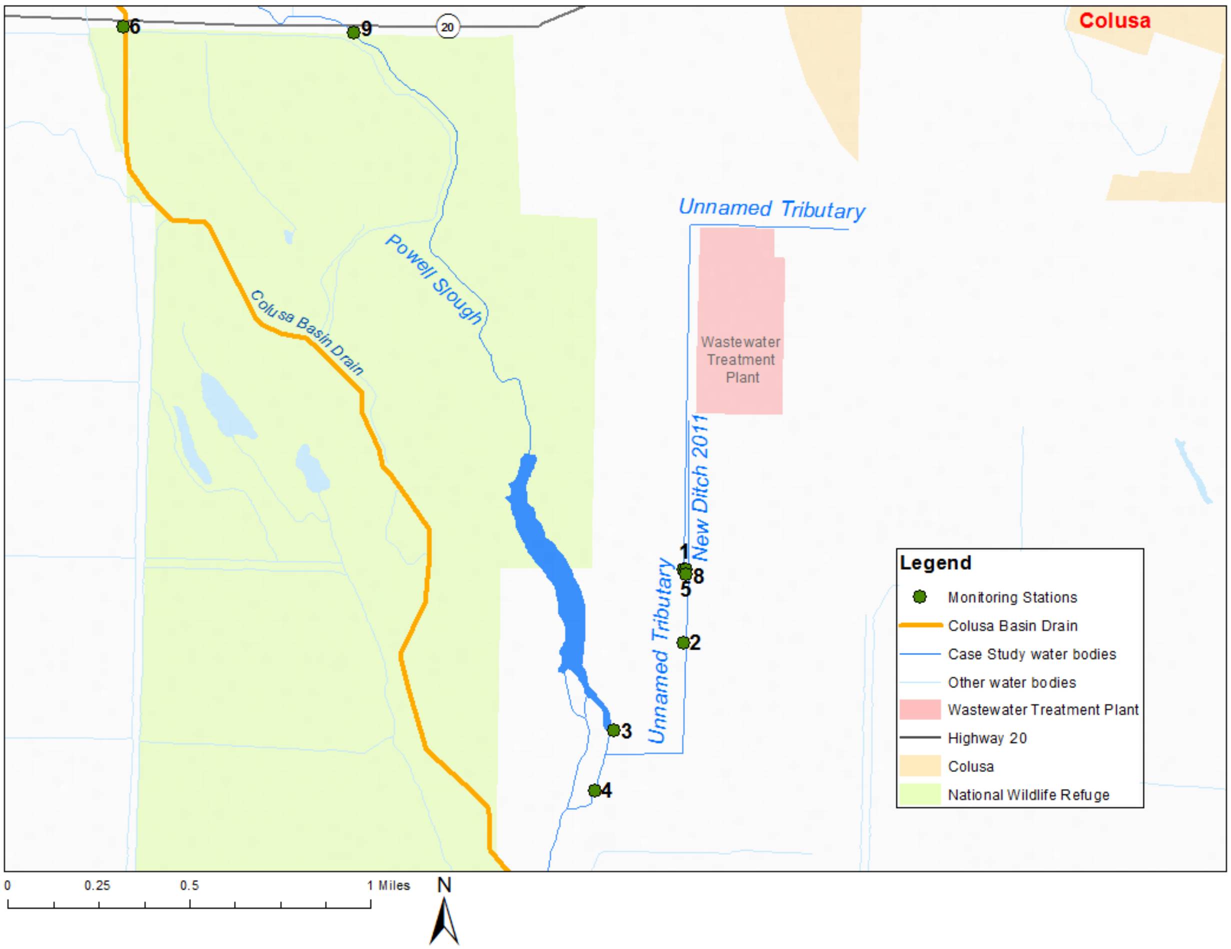
The City of Colusa Wastewater Treatment Plant (WWTP) is located southwest of the City of Colusa in Colusa County and serves 5,950 people (U.S. Census Bureau, 2013). Colusa WWTP's effluent is discharged into an unnamed tributary, a two mile long water body used for Ag drainage, prior to its confluence with Powell Slough. The water in the unnamed tributary is made up of irrigation discharge and urban runoff from the City of Colusa. Historic maps show that the unnamed tributary was constructed by the mid-1900s for the purpose of conveying Ag drainage (Colusa County Resource Conservation District, 2013). In 2011, an almost one half-mile new ditch that flows into the unnamed tributary, upstream of the effluent discharge, was also constructed for Ag drainage as well as groundwater pumped from new wells that were also recently installed on the landowner's property. The City of Colusa discharges their treated effluent directly downstream of the confluence of the new ditch and the unnamed tributary. The unnamed tributary extends for a little over a mile after the effluent discharge point, receiving Ag runoff from several adjacent fields before it enters Powell Slough.

Powell Slough, from near Highway 20, flows for approximately five miles prior to entering the Colusa Basin Drain. Its confluence with the unnamed tributary is less than a mile upstream of Colusa Basin Drain. Powell Slough is bordered primarily by Ag land and was modified in the early 1930s to facilitate irrigation and drainage (City of Colusa, 2010). Rice is the principal Ag crop in the area. Powell Slough receives much of its water supply during the irrigation season from the Colusa Basin Drain via an overflow channel that runs alongside Highway 20 from the Colusa Basin Drain to Powell Slough. Other hydro-modifications were made to Powell Slough such as the installation of a weir directly upstream of its confluence with the unnamed tributary (see Photo 1). Water is stored in the slough during the irrigation season and a pump station installed upstream of the weir provides water to neighboring fields (Photo 2). There is also a pump nearby on the Colusa Basin Drain that is used to supply water to a farm that drains into Powell Slough. Water in this area is managed primarily by the Colusa Drain Water Users Association and Reclamation District 2047. Figure 2 shows a map of the Colusa Subarea and the water quality monitoring stations listed in Section 5, Table 1.

Photo 1 Weir on Powell Slough (3/6/2012)

Photo 2 Pump station on Powell Slough (3/6/2012)

Figure 2 Colusa Study Area



4.1.2 Willows Subarea

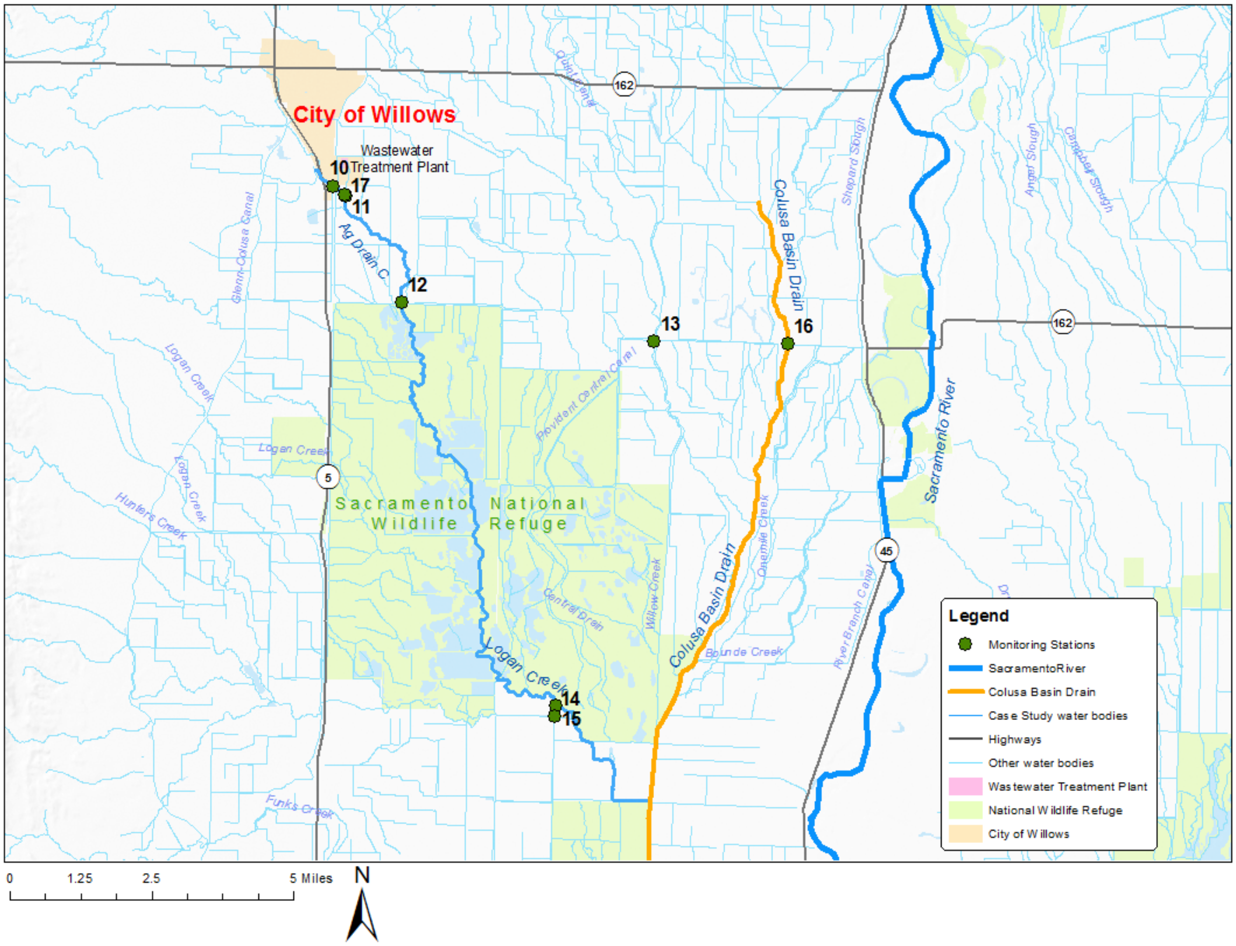
The City of Willows WWTP is located southwest of the City of Willows in Glenn County and serves 6,100 people (U.S. Census Bureau, 2013). The WWTP's effluent is currently only discharged into Ag Drain C, a 17 mile reconstructed segment of Logan Creek. Ag Drain C is part of the Glenn Colusa Irrigation District and was significantly modified in the early 1900s to facilitate Ag drainage (Glenn Colusa Irrigation District, 2012). Ag Drain C flows south through surrounding rice fields and the Sacramento River National Wildlife Refuge before eventually draining to the Colusa Basin Drain. Water drains from neighboring fields to Ag Drain C throughout its extent upstream of the wildlife refuge and the water may be recycled back as irrigation to downstream parcels via a number of adjacent canals, laterals and drains. After leaving the refuge, water from Ag Drain C continues east downstream to the Colusa Basin Drain.

Photos 3 and 4 show examples of hydro-modifications to Ag Drain C. Figure 3 is a map of the Willows Subarea and the water quality monitoring stations utilized as part of the study and listed in Section 5, Table 1.

Photo 3 Weir on Ag Drain C prior at Road 60 (5/9/2012)

Photo 4 Dam in wildlife refuge (4/17/2012)

Figure 3 Willows Study Area



4.2 East Side of the Sacramento River Basin – Lower Butte Creek Watershed and Sutter Bypass

Butte Creek Watershed spans approximately 500,000 acres on the east side of the Sacramento River, starting in Lassen National Forest and ending at the Sacramento River just north of the City of Sacramento. Much like the Colusa Basin, this area of the Sacramento River Basin was converted to agriculture during the 19th century. The Lower Butte Creek Watershed, starting near the City of Chico, includes a complex system of constructed water supply diversions, canals, Ag drains, levees, and bypasses and surrounds the Sutter Buttes, a small mountain range. Lower Butte Creek is surrounded almost entirely by Ag lands, including several state and federal wildlife refuges. Much of Butte Creek is contained by a series of levees. Its flow at the Butte Slough Outfall can be either directed into the Sacramento River, or regulated to accommodate Ag demands, flood flows and water supply to the wildlife refuges via the Sutter Bypass and Butte and Sacramento Slough areas. Under normal flow conditions, Butte Creek enters the Sacramento River via the Sacramento Slough, immediately upstream of the mouth of the Feather River near Verona.

The Sutter Bypass is a levied channel along the southwest portion of the Sutter Basin and was constructed as part of the Lower Sacramento Valley Flood Control Project in the early 1900s to protect surrounding Ag and urban areas during flood events and provide drainage during the irrigation season. The bypass allows channeling of escapement flow from the Sacramento River, but also receives drainage from Snake River, Gilsizer Slough, Wadsworth Canal, and other west side watercourses of the Lower Feather Watershed. During the non-storm season, flows are managed for Ag use and many of these water bodies may be used for both irrigation supply and drainage. Crops in the eastern portion of the Sacramento River Basin include a mixture of orchards, rice and row crops.

Beneficial uses of Butte Creek (downstream of Chico), Butte Slough and Sutter Bypass are specifically identified in the Basin Plan, and MUN is not a designated use of these water bodies.

4.2.1 Live Oak Subarea

The City of Live Oak WWTP is located on the southwest side of the City of Live Oak in Sutter County and serves 8,461 people (U.S. Census Bureau, 2013). The WWTP's effluent is discharged into Lateral 2, an approximately one half-mile long Ag drain, which flows downstream to another Ag drain, Lateral 1. Lateral 1 extends downstream for approximately five miles to the two mile segment of Western Interceptor Canal prior to meeting East Interceptor Canal. The East Interceptor Canal is approximately one and one-half miles long and flows westward to Wadsworth Canal. Wadsworth Canal flows southwest for almost five miles before it ends at the Sutter Bypass.

These receiving waters upstream of the Sutter Bypass are constructed channels and are used by Reclamation District 777 and portions of Reclamation District 2056 to convey Ag drainage water. This area of the valley has a mixture of agricultural crops and a number of nut producing orchards. Laterals 1 and 2 are part of Reclamation District 777 system and were constructed by the early 1900s to provide Ag drainage. Ag drainage to Lateral 2 has diminished considerably in recent years due to the installation of drip irrigation to nearby orchards. Western Intercepting Canal is shared by Reclamation Districts 777 and 2056 and also serves to convey Ag drainage. Sutter Extension and Butte Water Districts also operate and supply water in this area. Supply water sources include the Feather River and groundwater wells (Reclamation District 777, 2012).

As part of the "Butte Sink", this area is known for its shallow water table which causes groundwater seepage to surface water bodies. As the low point in the valley, large scale flooding was common prior to levees being built throughout the area. Segments of the Wadsworth Canal and the East Interceptor canal were initially constructed by local farmers in the late 1800s and early 1900s to both protect their property and crops from flooding and to serve as Ag drainage facilities. The State of California upgraded the construction of the

Wadsworth Canal to the Sutter Bypass in 1924. Both the Wadsworth Canal and the East Interceptor Canal were widened and enlarged by the United States Army Corp of Engineers in the 1940s as part of flood control projects.

Photo 5 shows Lateral 1, south of City of Live Oak and Photo 6 is a picture of the East Interceptor Canal. Figure 4 is a map of the Live Oak subarea and the water quality monitoring stations listed in Section 5, Table 1.

Photo 5 Lateral 1 at Clark Road (4/18/12)

Photo 6 East Interceptor Canal at Pease Road (4/18/12)

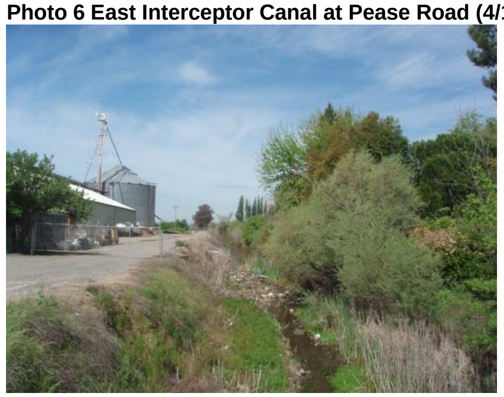
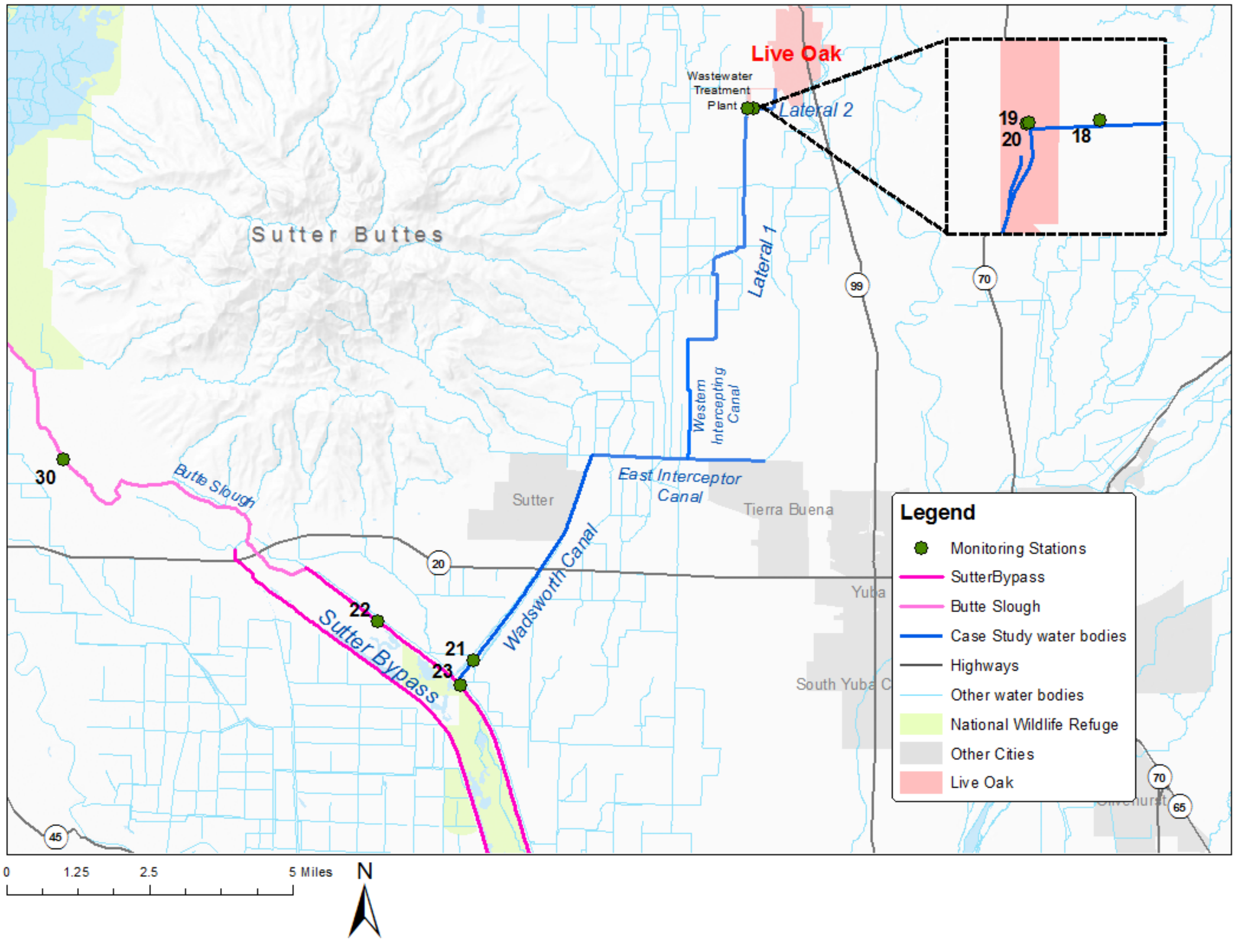


Figure 4 Live Oak Study Area



4.2.2 Biggs Subarea

The City of Biggs WWTP is located on the southwest side of the City of Biggs in Butte County and serves 1,710 people (U.S. Census Bureau, 2013). The WWTP's effluent is discharged into Lateral K, a 1.7 mile constructed Ag drain that is part of Reclamation District 833. Lateral K flows downstream to the Main Drainage Canal which is a constructed extension of Hamilton Slough on the east side of the City of Biggs. The Main Drainage Canal was constructed for the purpose of conveying Ag drainage and it flows southwest for almost 13 miles to its confluence with the Cherokee Canal and then eventually to Butte Creek. There are a number of dams along Main Drainage Canal as well as a network of adjacent laterals and drains to the neighboring parcels that produce rice and other mixed crops. Photo 7 shows supply water spilling to the Main Drainage Canal just downstream of its confluence with Lateral K. Photo 8 shows an example of another hydro-modification in the Main Drainage Canal upstream of its confluence with the Cherokee Canal. The Main Drainage Canal widens prior to the Colusa Highway and receives urban runoff from the cities of Biggs and Gridley. Water from the receiving water bodies downstream of the Biggs WWTP may be distributed throughout Reclamation District 833 and portions of Reclamation District 1004. The Biggs-West Gridley Water District is also located in the vicinity and provides water to farmers and to the Gray Lodge National Wildlife Refuge.

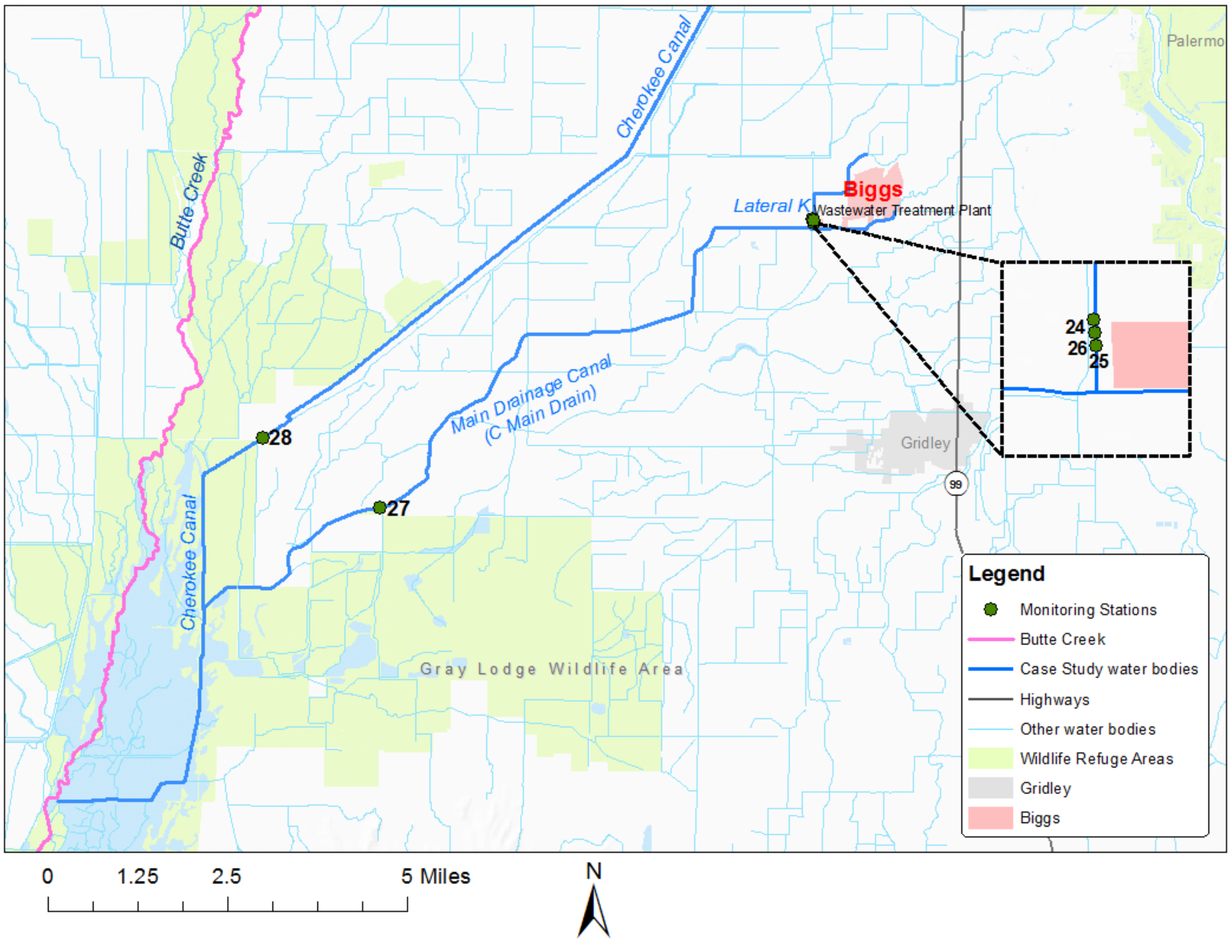
The Cherokee Canal extends for over 22 miles from north of Biggs to Butte Creek. The headwaters of the Cherokee Canal originate in Dry Creek, Cottonwood Creek and Gold Run Creek near the City of Chico. Segments of the canal were initially constructed for Ag drainage by local interests in the late 1800s and early 1900s. Early on, the wastewater from mining operations upstream in Cherokee was channeled for Ag use in the Sacramento Valley. The canal was expanded as part of the Cherokee Canal Channel Improvement and Levee Construction Project, which was authorized by Congress in 1944 for flood protection. During the growing season, water is conveyed in the channel for Ag use. Water from the Cherokee Canal after its confluence with the Main Drainage Canal is also used for the private Duck Clubs located near the Butte Creek.

Figure 5 is a map of the Butte Subarea and water quality monitoring stations listed in Section 5, Table 1.

Photo 7 Supply Canal Spill into Main Drainage Canal (3/21/2012)

Photo 8 Main Drainage Canal at Liberty Road (3/21/2012)

Figure 5 Biggs Study Area



NOTE: Monitoring sites on Butte Creek and Butte Slough can be seen in Figure 1.

5.0 WATER QUALITY MONITORING PROGRAM

Water quality monitoring was conducted over an 18-month period (April 2012—September 2013) to help characterize both background conditions and potential influence of effluent discharges on the receiving waters for each POTW. All monitoring was conducted following the State of California Surface Water Ambient Monitoring Program (SWAMP) Protocol.

5.1 Program Objectives

The primary objectives of the water quality monitoring project were:

- Characterize Receiving Waters; and
- Determine spatial and temporal influence of effluent discharged from identified POTWs

5.2 Program Design

To leverage resources, provide access, and insure transparency, the project was coordinated with the CV-SALTS initiative, ILRP coalitions, local POTWs and other local, state, and federal stakeholders including the water agencies that are currently managing and maintain the water bodies in question.

The water quality-monitoring program was conducted in the Sacramento River Basin from April 2012 – September 2013. In order to characterize receiving waters, Central Valley Water Board staff met with the POTWs, Irrigation and Reclamation districts in order to determine safe and accessible sampling sites while following the hydrology of the system.

A total of 28 sampling sites were selected and are listed by POTW evaluated in Table 1.

Table 1 Sampling Site Locations Monitored During Sacramento River Basin MUN Study, April 2012—September 2013

Location	Map Label	Sites	Station Code	Latitude	Longitude
City of Colusa	1	**Unnamed tributary** to Powell Slough, **upstream** of the effluent discharge.	520COL106	39.17427	-122.03138
	2	**Unnamed tributary** to Powell Slough, **downstream** of the effluent discharge	520COL105	39.17138	-122.03132
	3	**Powell Slough, upstream** of the confluence of the unnamed tributary and Powell Slough	520COL003	39.16779	-122.03479
	4	**Powell Slough**, **downstream** from the confluence of the unnamed tributary and Powell Slough.	520COL102	39.1654	-122.03571
	5	**New Ditch**, **upstream** of the effluent discharge.	520COL107	39.17427	-122.03125
	6	**Colusa Basin Drain** at Highway 20 **upstream** of effluent discharge	520COL006	39.1955	-122.06083
	7	**Colusa Basin Drain** at Abel Road **downstream** of effluent discharge	520COL101	39.14463	-122.02734
	8	**Effluent Monitoring Station**	n/a	39.18763	-122.02941
	9	**Powell Slough** at Highway 20 **upstream** of effluent discharge	520COL005	39.19545	-122.04893
City of Willows	10	**Ag Drain C, upstream** ~1500 feet of the effluent discharge at Highway 99W.	520GLE005	39.49469	-122.19308
	11	**Ag Drain C, downstream** ~100 feet of the effluent discharge.	520GLE004	39.49233	-122.18903
	12	**Ag Drain C, downstream** of effluent discharge before entering the Wildlife Refuge at Road 60	520GLE003	39.46569	-122.16961
	13	**Willow Creek** at Road 61**upstream** of effluent discharge	520GLE001	39.45747	-122.08609
	14	**Hunter Creek** at 4 Mile Road **downstream** of effluent	520COL108	39.3626	-122.11622
	15	**Logan Creek** at 4 Mile Road **downstream** of effluent	520COL109	39.3652	-122.11597
	16	**Colusa Basin Drain** at Road 61 **upstream** of effluent discharge	520GLE002	39.4575	-122.04198
	17	**Effluent Monitoring Station**	n/a	39.50187	-122.19133

Table 1 continued: Sampling Site Locations Monitored During Sacramento River Basin MUN Study, April 2012—September 2013

Location	Map Label	Sites	Station Code	Latitude	Longitude
City of Live Oak	18	**Lateral Drain #2**, **upstream** ~50 feet of effluent discharge	520SUT008	39.2598	-121.67607
	19	**Lateral Drain #2**, **downstream** ~ 200 feet of effluent discharge	520SUT007	39.25976	-121.67794
	20	**Effluent Monitoring Station**	n/a	39.26029	-121.677975
	21	**Wadsworth Canal**, **downstream** of effluent discharge	520SUT005	39.11893	-121.76402
	22	**Sutter Bypass**, **upstream** of effluent discharge and the Wadsworth Canal confluence	520SUT006	39.12836	-121.79546
	23	**Sutter Bypass**, **downstream** of effluent discharge and the Wadsworth Canal confluence	520SUT004	39.1125	-121.76814
City of Biggs	24	**Lateral K – Upstream** ~100 feet of effluent discharge	520BUT004	39.40863	-121.72537
	25	**Lateral K – Downstream** ~ 100 feet of effluent discharge	520BUT003	39.40797	-121.7253
	26	**Effluent Monitoring Station** – pipe prior to entering Lateral K	n/a	39.40827	-121.72533
	27	**C Main Drain**, **downstream** of effluent discharge at dam before Cherokee Canal confluence	520BUT001	39.3488	-121.83657
	28	**Cherokee Canal**, **upstream** of effluent discharge at Colusa Highway.	520BUT002	39.36247	-121.86745
	29	**Butte Creek**, **upstream** of effluent discharge at Nelson Road	520BUT902	39.55569	-121.83652
	30	**Butte Slough**, **downstream** of effluent discharge at Farmlan	520COL104	39.1675	-121.89874

Grab samples were collected at all sites and included field measurements of specific conductance (SC), pH, turbidity, dissolved oxygen (DO), and temperature. In addition, photos were taken during each site visit to visually document changing conditions including water levels. Additional field measurements from April 2013 – September 2013 were collected by the POTWs and submitted to Central Valley Water Board staff in order to maximize limited resources and provide a more complete temporal record.

Depending on the site and constituent of interest, monitoring was conducted once a month, twice a month, annually, or quarterly. Monitoring of constituents was also dependent on the quarterly reviews which were based on where and how frequent elevated concentrations were detected. Quarterly scans in 2012 occurred in June and September and quarterly scans in 2013 occurred in January, March, June, and September. Ammonia as nitrogen was sampled once a month at the Biggs study area and annually at the effluent site of the Colusa, Willows, and Live Oak study area. *Escherichia coli (E. coli)* was later added and sampled once a month from August 2012 – September 2013. Key constituents consists of constituents that were identified in the effluent during the POTW's NPDES permit renewal process at concentrations that may exceed the evaluation criteria for protecting drinking water supplies, constituents of potential concern through ILRP analyses, and constituents that had frequent elevated concentrations detected during monitoring. The following shows the sampling frequency of key constituents for the period of April 2012 through September 2013:

Field (Two times/Month):

- Dissolved Oxygen
- pH
- Water Temperature
- Turbidity
- Specific Conductance
- Photos

Bacteria (Monthly):

- *E. coli*

Key (Monthly):

- Ammonia as N
- Nitrate as N
- Sulfate
- Total Dissolved Solids
- Boron
- Dissolved Arsenic
- Total Arsenic
- Sodium

General (Quarterly):

- Chloride
- Flouride
- Perchlorate
- Dissolved Aluminum
- Dissolved Iron
- Dissolved Manganese
- Total Aluminum
- Total Antimony
- Total Arsenic
- Total Barium
- Total Berrylium
- Total Cadmium
- Total Chromium
- Total Copper
- Total Iron
- Total Lead
- Total Manganese
- Total Mercury
- Total Nickel
- Total Selenium
- Total Silver
- Total Thallium
- Total Zinc

Trihalomethanes (Quarterly):

- Bromoform
- Chloroform
- Bromodichloromethane
- Dibromochloromethane

Limited funding allowed for one full scan of all four POTW's effluents in June 2012. In addition to the constituents listed above, the full scan consisted of the following scans: Volatile Organic Compound and Oxygenated Additive; Organo-Chlorinated Pesticides; Gas Chromatograph/Mass Spectrometer Semivolatiles; Chlorinated Herbicides; Organo-Phosphorus Pesticides; Polychlorinated Biphenyls; Poly-Chlorinated-Dibenzo-p-Dioxin/Furan High Resolution Mass Spectrometer; and Carbamate Pesticides. Constituents within each scan are detailed in Table 2. Not all of the constituents listed within each scan have MUN water quality evaluation criteria.

Table 2 List of Constituents Within Each Scan

Scan	Test Method	Constituent
Volatile Organic Compound & Oxygenated Additive	8260B	1,1-Dichloroethane, 1,1-Dichloroethene, 1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,2-Dichlorobenzene, 1,2-Dichloroethane, cis-1,2-Dichloroethene, 1,2-Dichloropropane, 1,2,4-Trichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, Acrolein, Acrylonitrile, Benzene, Bromoform, Bromomethane, Carbon tetrachloride, Chlorobenzene (mono chlorobenzene), Chloroethane, Chloroform, Chloromethane, Dibromochloromethane, Dichloromethane, Ethylbenzene, Hexachlorobenzene, Hexachlorobutadiene, Hexachloroethane, Naphthalene, Tetrachloroethene, Toluene, trans-1,2-Dichloroethylene, Trichloroethene, Vinyl chloride, Methyl-tert-butyl ether (MTBE), Trichlorofluoromethane, 1,1,2-Trichloro-1,2,2-Trifluoroethane, Styrene, Xylenes, 1,2-Dibromo-3-chloropropane (DBCP), Ethylene Dibromide, 1,1,1,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloropropene, 1,2,3-Trichloropropane (123TCP), 1,2,4-Trimethylbenze, 1,2-Dibromoethane (EDB), 1,3,5-Trimethylbenze, 1,3-Dichloropropane, 2,2-Dichloropropane, 2-Hexanone, 4-Chlorotoluene, 4-Methyl-2-pentanone, Acetone, 4-Methyl-2-pentanone, Bromobenzene, Bromochloromethane, Carbon disulfide, cis-1,3-Dichloropropene, Dichlorodifluoromethane, Dichloromethane, Isopropylbenzene, m,p-Xylene, Methylene chloride, n-Butylbenzene, n-Propylbenzene, o-Xylene, p-Isopropyltoluene, tert-Butylbenzene
Organo-Chlorinated Pesticide	8081A	4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-Hexachlorocyclohexane (BHC), Aldrin, beta-Hexachlorocyclohexane, Chlordane, Dieldrin, Endosulfan sulfate, Endrin, Endrin Aldehyde, Heptachlor, Heptachlor Epoxide, Lindane (gamma-Hexachlorocyclohexane), Toxaphene, alpha-Chlordane, delta-BHC, Endosulfan I, Endosulfan II, Endrin ketone, gamma-Chlordane, Methoxychlor, Trifluralin
Gas Chromatography/Mass Spectrometer (GC/MS) Semivolatiles	8270C	1,2-Diphenylhydrazine, 2-Chlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2,4-Dinitrotoluene, 2,4,6-Trichlorophenol, 2,6-Dinitrotoluene, 2-Nitrophenol, 2-Chloronaphthalene, 3,3'-Dichlorobenzidine, 4-Chloro-3-methylphenol, 4,6-Dinitro-2-methylphenol, 4-Nitrophenol, 4-Bromophenyl phenyl ether, 4-Chlorophenyl phenyl ether, Acenaphthene, Acenapthylene, Anthracene, Benzidine, Benzo(a)pyrene (3,4-benzopyrene), Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Bis(2-chloroethoxy) methane, Bis(2-chloroethyl) ether, Bis(2-chloroisopropyl) ether, Bis(2-ethylhexyl) phthalate, Butyl benzyl phthalate, Chrysene, Di-n-butylphthalate, Di-n-octylphthalate, Dibenzo(a,h)-anthracene, Diethyl phthalate, Dimethyl phthalate, Fluoranthene, Fluorene, Hexachlorocyclopentadiene, Indeno(1,2,3-c,d)pyrene, Isophorone, N-Nitrosodiphenylamine, N-Nitrosodimethylamine, N-Nitrosodi-n-propylamine, Nitrobenzene, Pentachlorophenol, Phenanthrene, Phenol, Pyrene, 2,4,5-Trichlorophenol, 2-Methylnaphthalene, 2-Methylphenol, 2-Nitroaniline, 3-Hydroxycarbofuan, 3-Methylphenol , 3-Nitroaniline, 4-Chloroaniline, 4-Methylphenol, 4-Nitroaniline, Benzo (a) anthracene, Benzo (b) fluoranthene, Dibenzofuran, Dibromochloropropane, Diphenylamine, Isophorone
Chlorinated Herbicide	8151A	2,4-D, Dalapon, Dinoseb, Picloram, 2,4,5-TP (Silvex), 2,4,5-T, 2,4-DB, Dicamba, Dichloroprop, MCPA, MCPP,
Organo-Phosphorus Pesticide	8141A	Atrazine, Simazine (Princep), Diazinon, Chlorpyrifos, Azinphos methyl, Bolstar, Coumaphos, Demeton O/S, Dichlorvos, Disulfoton, Ethoprop, Fensulfothion, Fenthion, Merphos, Methyl parathion, Mevinphos, Naled, Phorate, Stirophos (Tetrachlorvinphos), Trichloronate
Polychlorinated Biphenyls (PCB's)	8082A	PCB-1016, PCB-1221, PCB-1232, PCB-1242, PCB-1248, PCB-1254, PCB-1260
Poly-Chlorinated-Dibenzo-p-Dioxin/Furan High Resolution Mass Spectrometer (HRMS)	8290	2,3,7,8-TCDD (Dioxin)
Carbamate Pesticide	8318	Carbofuran, Oxamyl, 3-Hydroxycarbofuran, Aldicarb, Aldicarb sulfone, Carbaryl, Dioxacarb, Methiocarb, Methomyl, Promecarb, Propoxur (Baygon)

5.3 Sampling Sites

Sampling sites are depicted as green circles in Section 4, Figures 1—5. Sampling sites were chosen in coordination with reclamation districts and irrigation districts. The criterion for choosing a sampling site was safe access and reasonable characterization of the receiving waters both upstream and downstream of wastewater effluent discharges. A summary of photos throughout the 18-month study period are presented for each site in Appendix A.

5.3.1 Colusa Subarea Sites

The City of Colusa's NPDES permit requires monitoring both upstream and downstream of their effluent discharge on the unnamed tributary. In addition, their permit includes monitoring sites on Powell Slough, upstream and downstream of its confluence with the unnamed tributary. All four sites were included as part of this monitoring program. An additional site was added on the new ditch, upstream of its confluence with the unnamed tributary, to provide a more complete picture of the water quality upstream of the city's effluent. A third site on Powell Slough was added several miles upstream of the unnamed tributary at Highway 20. This site is located prior to the hydro-modifications seen south of Highway 20 and receives periodically water flow from the Colusa Basin Drain via a ditch that runs along Highway 20. Two sites were selected along Colusa Basin Drain, the furthest upstream at Highway 20 and the other downstream past its confluence with Powell Slough at Abel Road. These two sites are about 4 miles apart (See Figure 2 in Section 4).

5.3.2 Willows Subarea Sites

This study included the two receiving water monitoring stations that the City of Willows is required to monitor as part of their NPDES permit, upstream and downstream of their effluent discharge on Ag Drain C. An additional downstream site was selected on Ag Drain C at Road 61, prior to the channel entering the Sacramento Wildlife Refuge. A further downstream site was selected at Logan Creek at 4 Mile Road, prior to their combined flow entering the Colusa Basin Drain. Hunter Creek is close to Logan Creek but does not receive any POTW effluent and is used as a comparison site only. The water quality of the Colusa Basin Drain upstream of any effluent influences was characterized using sites at the Colusa Basin Drain at Road 61 and as well as Willow Creek at Road 61. Willow Creek is a significant contributor to flow in the Colusa Basin Drain upstream its confluence with Logan Creek. Since there was no accessible sampling site along the Colusa Basin Drain directly upstream of its confluence with Logan Creek and downstream of its confluence with Willow Creek, the two upstream sites on Road 61 were selected to ensure that the upstream conditions were accurately captured. There are about 15 miles between the Ag Drain C sites near the effluent discharge and the Logan Creek site at 4 Mile Road (See Figure 3 in Section 4).

5.3.3 Biggs Subarea Sites

The Biggs study area was the largest amongst all of the POTW study areas due to distance between water bodies and accessibility of sites. About 55 miles separates the furthest upstream site at Butte Creek near Nelson Road to the furthest downstream site at Butte Slough near Farmlan Road. The Butte Creek site near Nelson Road is also a site that has historic data collected by the Department of Water Resources. The City of Biggs monitors both upstream and downstream of their effluent discharge on Lateral K for their NPDES permit and these two sites were maintained for this study as well as an additional site downstream on the C Main Canal prior to its confluence with the Cherokee Canal. Because the Cherokee Canal is a significant contributor to flow that eventually goes to the Butte Slough, an upstream site was selected at the Colusa Highway, upstream of its confluence with the C Main Canal. This site has also been used as an assessment site for the Irrigated Regulatory Lands Program (See Figure 4 in Section 4).

5.3.4 Live Oak Subarea Sites

This monitoring program used the same sites regulated in the NPDES permit for the City of Live Oak, upstream and downstream of their wastewater effluent discharge into Lateral 2. An additional downstream site was added on the Wadsworth Canal prior to its confluence with the Sutter Bypass. Upstream and downstream sample stations were selected on the Sutter Bypass near its confluence with the Wadsworth Canal. The distance from the Lateral 2 drain sample site to the Sutter Bypass sample site is about 18 miles (Figure 5 in Section 4).

5.4 Sampling Procedures

Collection of all water samples were in compliance with the Procedures Manual for the San Joaquin River Water Quality Monitoring Program (Central Valley Water Board, 2010) which is compliant with the 2008 SWAMP Quality Assurance Program Plan (QAPrP) for the State of California's Surface Water Ambient Monitoring Program (State Water Resources Control Board, 2008).

All water samples were collected as grab samples approximately three feet from the bank. After collection, all samples were kept at 4ºC while in transit to the laboratory. Excelchem Environmental Labs, Moore Twining Associates, Sierra Foothill Laboratory, City of Yuba City Water/Wastewater Laboratory, Basic Laboratory, and BSK Associates conducted all contracted laboratory analyses throughout the sampling period.

Samples collected for total coliform and *E. coli* were analyzed using the IDEXX® Colilert-18 method (Analytical methods 9223B in STANDARD METHODS, EDITION 20) at the Central Valley Water Board laboratory. Results using the Colilert method are reported in terms of Most Probable Number (MPN/100 mL).

Total Dissolved Solids (TDS), nitrate, chloride, fluoride, perchlorate, and sulfate samples were collected in polyethylene bottles, which were triple-rinsed with source water prior to sample collection.

Volatile Organic Compounds (VOC) samples were collected in glass VOA (volatile organic analysis) vials at the POTWs sites and at the first downstream site. Three VOA vials were used for collection at each site. Each VOC sample was collected in a stainless steel container that was attached to a sampling pole and triple rinsed with source water prior to sample collection. Sample water was then slowly poured into three 40-mL, pre-acidified with hydrochloric acid, VOA vials.

The Yellow Springs Instruments (YSI) Sonde Model 600XLM was used to measure temperature, pH, dissolved oxygen (DO), and specific conductance (SC) in the field. The HACH Turbidometer 2100P was used to measure turbidity also in the field.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance (QA) and quality control (QC) logs for constituents analyzed by outside labs are maintained by the Contract Manager or designee. The QA/QC logs for bacteria analysis is recorded in the QA/QC logbook, found in the Central Valley Water Board laboratory where samples are analyzed.

Field and handling contamination were evaluated by submitting blind travel blanks and field duplicates on each run. For metals, nitrate, ammonia, VOC, MBAS, pesticide, herbicide, boron and sodium, the travel blank consisted of a sample of deionized water that was collected at the Central Valley Water Board laboratory. For bacteria monitoring, the travel blanks were made from Type II water prepared by the Atwill Water & Foodborne Zoonotic Disease Laboratory at UC Davis under the supervision of Dr. Rob Atwill. Type II water is autoclaved double deionized water. All blanks made with Type II water were negative for contamination. The travel blanks traveled through the sampling run, and were processed with the sample set.

Aside from four travel blanks, all results for travel blanks fell below the analytical detection limits for the elements of concern. The four travel blanks sampled on February 26th and 28th and May 20th and 21st in 2013 failed for Total Dissolved Solids (TDS). Reporting limit for TDS was 5.0 mg/L. Failed travel blank values ranged from 5—39 mg/L which is a low concentration detected in comparison to site values that ranged from 300-700 mg/L. There was not enough time to reanalyze due to the holding time of 7 days from sample collection date. The four travel blank failures are flagged in Appendix B; however, the data collected from the sampling sites has been included in this evaluation.

Consistency in sample collection was insured through a series of trainings of field crews.

Analytical precision was evaluated using blind duplicate samples. Blind duplicate samples were collected at a 5% frequency for each sampling event in two separate containers.

Field measurements collected by the POTWs followed their QA/QC requirements outlined in their Quality Assurance Project Plans. POTW field measurement data sets were included in the analysis.

Field Equipment and Analytical Methods

The Central Valley Water Board Ag Regulatory and Planning Unit practices a standard quality assurance procedure with all its sampling programs that includes calibration of sampling equipment prior, during, and after each sampling run. Calibration procedures can be found in the Procedures Manual for the San Joaquin River Water Quality Monitoring Program (Central Valley Water Board, 2010). Analytical methods utilized are listed in Appendix G.

Bacterial Analysis

Results for *E. coli* were recorded as Most Probable Number (MPN) per 100 ml of sample water and were detectable between 1 to 2419.6 MPN. Results above and below the counting limit were recorded as >2419.6 and <1, respectively.

Field duplicate bacteria samples were collected and analyzed to evaluate analytical precision. Lab duplicate samples were collected and analyzed in order to evaluate how the laboratory handled the samples. To develop lab duplicate samples, field samples were collected in 290 mL bottles and the sample was then split into separate containers in the lab. Sample collection frequency of both field and lab duplicate met SWAMP QA requirements

7.0 PRECIPITATION AND FLOW: APRIL 2012—SEPTEMBER 2013

The Sacramento Valley Water Year Type Index is used to classify the water year type in the Sacramento River Basin. The 40-30-30 Index includes five classifications: wet, above normal, below normal, dry, and critical. A Water Year begins 1 October and ends 30 September of the following year. The monitoring period of this study, April 2012—September 2013, represented the second half of Water Year 2012 and all of Water Year 2013. Both Water Year 2012 and Water Year 2013 was classified a dry year (DWR, 2013).

To document the hydrology within the study areas on both the east and west side of the Sacramento River basin, information on rainfall and flow were retrieved from long-term monitoring stations. Flow data from the Department of Water Resources California Data Exchange Center was recorded at Sutter Bypass at Road 1500 pump (SBP) and Colusa Drain Near HWY 20—Sacramento River (CDR) and utilized for characterizing the seasonal hydrology for the east and the west side conditions of the basin, respectively. Precipitation data from the Department of Water Resources California Irrigation Management Information System at Colusa in Colusa County (Station: 32) and Verona in Sutter County (Station: 235) was also utilized for characterizing the seasonal hydrology for the east and the west side of the basin, respectively.

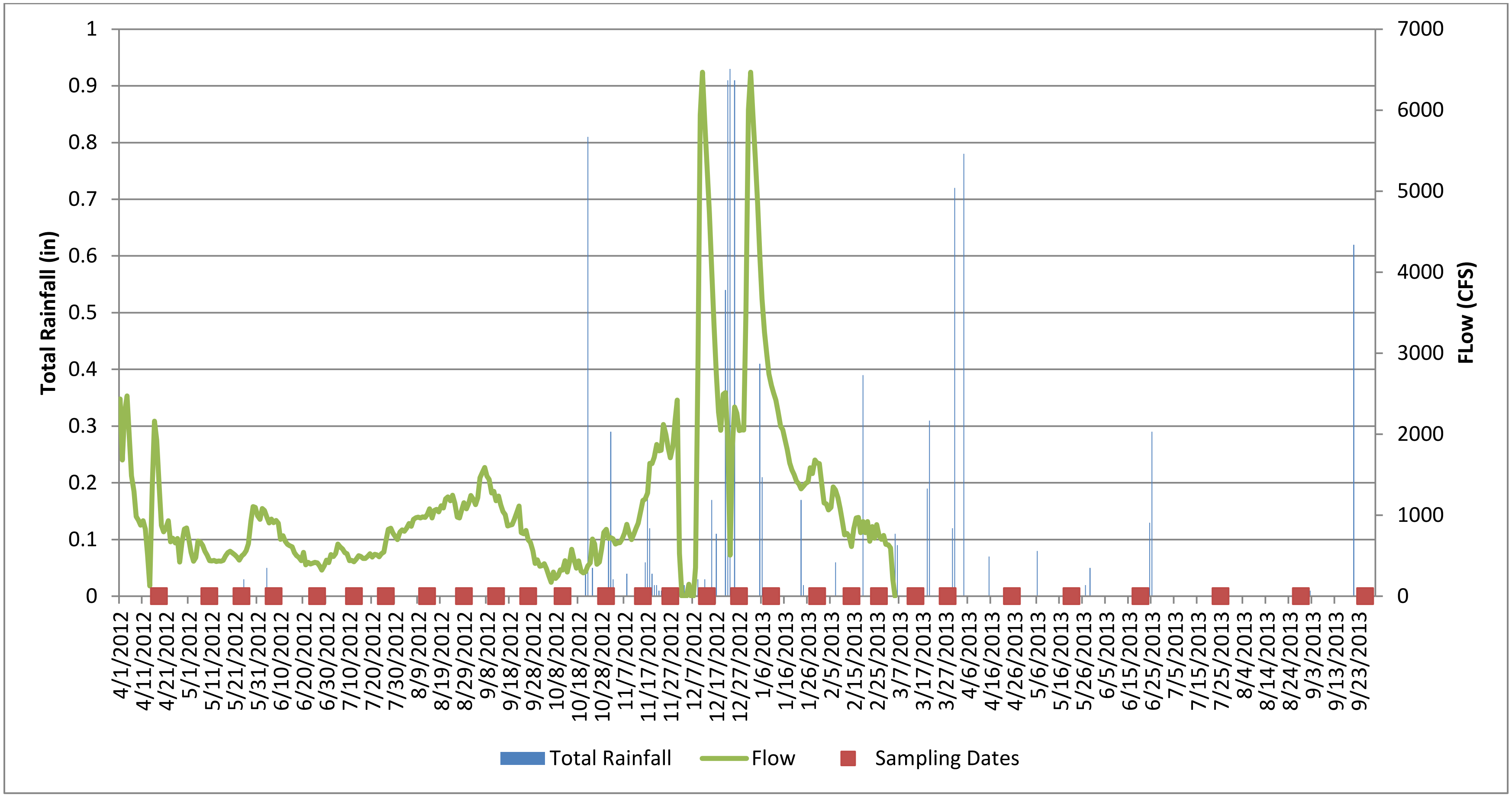
Figure 6 and 8 relate sampling events to flow and precipitation. The sampling schedule captured all hydrologic changes-dry periods, high/low flow, and high/low precipitation.

Generally, there was flow throughout the sampling period of April 2012 to September 2013 for the west side of the Sacramento River Basin. For the east side of the basin, flow data is not available from March 15, 2013 through September 30, 2013 (Figure 6). This was not a dry period according to the Sutter Bypass photo documentation in Appendix A and river stage data in Figure 7. Figure 7 compares flow and river stage data for the east side of the river basin. Although flow data is missing, there is river stage data gathered at the Sutter Bypass station. The pattern between flow and river stage are quite similar. Both had peaks during irrigation and storm periods. Based on the similarity between flow and river stage patterns for the period of April 1, 2012 through March 14, 2013, it was assumed that flow had a pattern similar to river stage for the period of March 15, 2013 to September 30, 2013.

In both the east and west side of the Sacramento River Basin, precipitation patterns were relatively similar (Figure 6 and 8, respectively). Precipitation in both the east and west side of the basins occurred primarily in the fall—spring period (October-April), with a few events falling outside of this period. There was a precipitation event on September 21, 2013, with daily total precipitation of 0.62 inches and 0.52 inches in the east and west side basin, respectively. During the fall/winter months (October 2012—January 2013), several precipitation events occurred, resulting in a period of high flows. During the fall/winter months, the east side basin's highest daily precipitation totaled up to 0.93 inches on December 23, 2012 and peaked with a flow of 6468 cfs on January 1, 2012. During those same months, the west side basin's highest precipitation totaled up to 1.22 inches on November 17, 2012 and peaked with a flow of 4186 cfs on December 6, 2012. The mean precipitation and flow in the east side basin during October 2012—January 2013 was 0.053 inches and 1681 cfs, respectively. The mean precipitation and flow in the west side basin during October 2012—January 2013 was 0.074 inches and 943 cfs, respectively. The average rainfall in the east side basin was lower than the west side basin; however, the average flow was higher, potentially due to snow melt contribution from the Sierra.

Flow peaked during irrigation periods (March—August) and storm periods (October—January) for both the east and west side of the Sacramento River Basin. Differences between the two sides of the basin were very minimal. There were higher peaks of flow in the month of April 2012 in the east side basin. The east side basin had a mean flow of 1152 cfs for the month of April 2012, whereas the west side basin had an average of 293 cfs. Another distinct peak of flow was seen around the first week of September 2012; the east and west side basin peaked at a flow of 1591 and 1341 cfs, respectively. Flow peaked at its highest for both the east and west side of the basin during storm periods. Peaks during the other parts of the year that cannot be accounted for by rain were most likely due to the highly managed water system. Both the east and west side of the basin are dominated by rice fields which have specific water management needs. Flood up of fields occur primarily during the months of April or May (depending on water supply) with water levels maintained until released in October or the first week of November.

Figure 6 Daily Flow vs. Daily Precipitation, East Side of Sacramento River Basin (April 2012—September 2013)



NOTE:

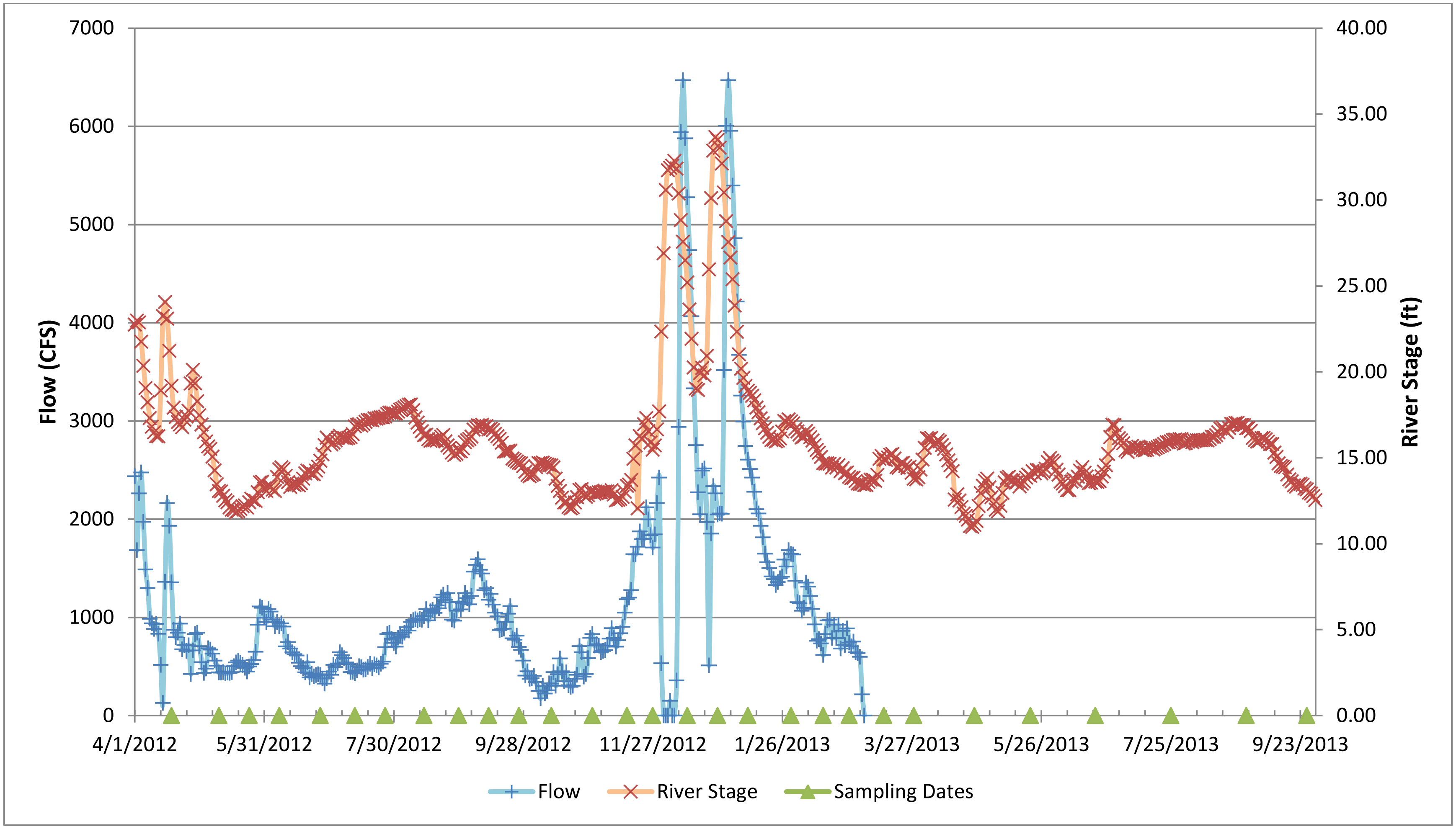
Total rainfall data source: CA Dept. of Water Resources CIMIS (Station: 235—Verona in Sutter County)

Flow data source: CA Dept. of Water Resources CDEC (Station: SBP—Sutter Bypass at Road 1500 pump)

Total rainfall data is not available from April 1, 2012—May 17, 2012.

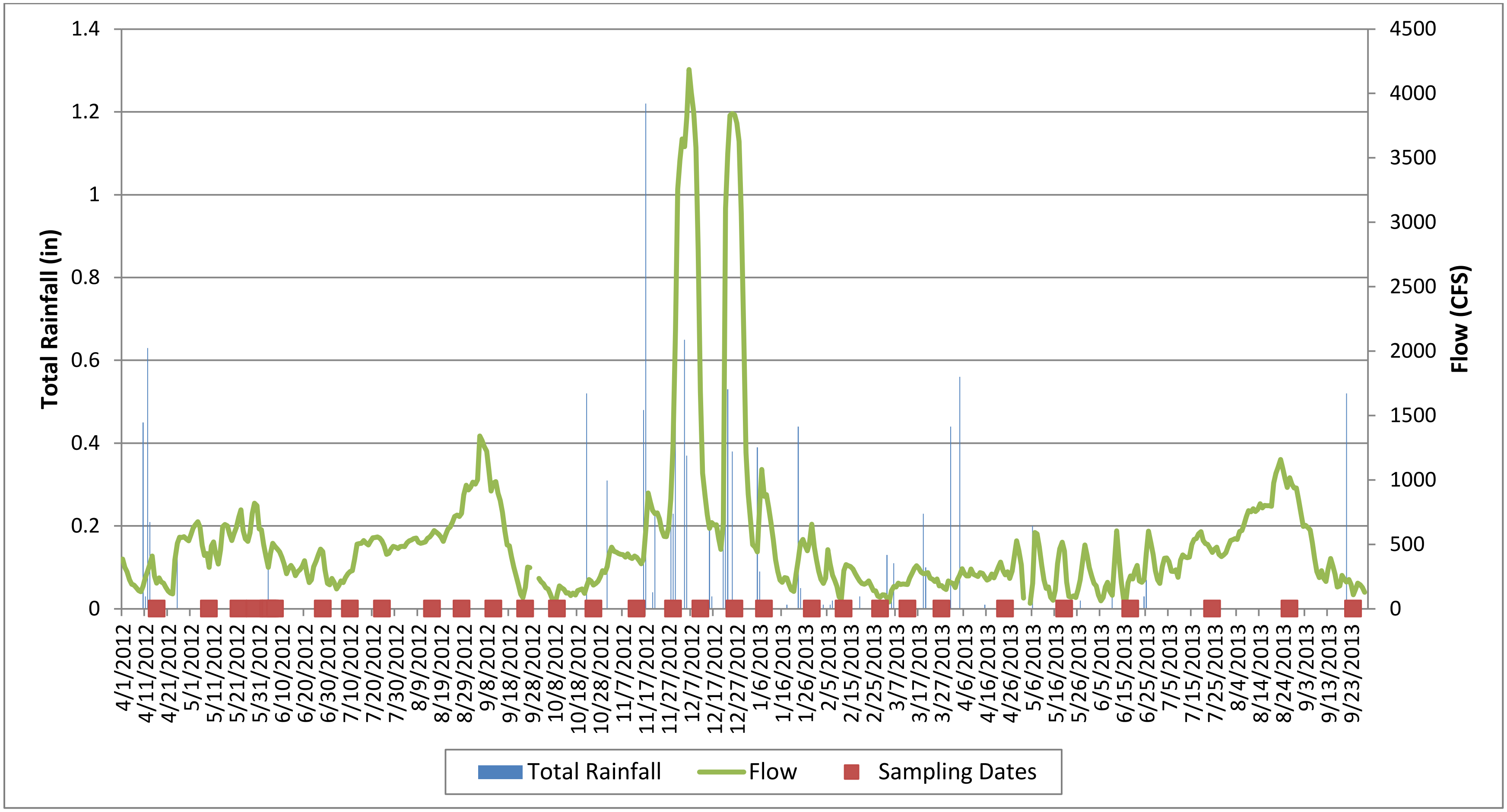
Flow data is not available from March 15, 2013—September 30, 2013.

Figure 7 Flow vs. River Stage, East Side of Sacramento River Basin (April 2012—September 2013)



NOTE: Flow and river stage data source: CA Dept. of Water Resources CDEC (Station: SBP—Sutter Bypass at Road 1500 pump)

Figure 8 Daily Flow vs. Daily Precipitation, West Side of Sacramento River Basin (April 2012—September 2013)



NOTE:

Total rainfall data source: CA Dept. of Water Resources CIMIS (Station: 32—Colusa in Colusa County)

Flow data source: CA Dept. of Water Resources CDEC (Station: CDR—Colusa Drain near HWY 20 (Sacramento River))

Total rainfall data is not available from November 22, 2012—November 25, 2012.

8.0 RESULTS

All data collected are presented in Appendix B through E. Summary tables for each constituent monitored were created using the appendix and are listed in this section. The summary tables have been organized by study area with Colusa and Willows information (Tables 4 and 5, respectively) comprising the west side and Biggs and Live Oak (Tables 6 and 7, respectively) comprising the east side. These tables provide a summary for all constituents monitored and include the count, minimum, mean, and maximum concentrations detected for each individual upstream, effluent, and downstream site of each study area. The evaluation criteria to protect human health is also listed for comparison, but not discussed until sections 9 and 10.The constituents are also categorized by frequency of monitoring—two times a month, monthly, or quarterly. Photo monitoring is depicted in Appendix A.

Additional field measurements (SC, pH, turbidity, DO, and temperature) were collected by the POTWs and submitted to Central Valley Water Board staff in order to maximize limited resources and provide more complete temporal information. Colusa's POTW submitted field data that was collected once for the month of June 2012, June and July 2013; Willow's POTW submitted field data for the month of April, July, August, and September 2013; Live Oak's POTW submitted field data for the month of May, June, and August 2012 and April, May, June, July, August, September 2013; and Biggs' POTW submitted field data for the month of August 2012 and April, May, August, and September 2013. The California Department of Water Resources (DWR) submitted field data for the month of August 2012 for the Biggs study area. This additional information has been included in the appendix and tables.

E. coli samples were detectable between 1 to 2419.6 MPN/100mL. Results above and below the reporting limit were recorded as >2419.6 MPN/100mL and <1 MPN/100mL, respectively. For calculation and graphing purposes, for any results that were above or below the reporting limit, the respective reporting limits were used.

For all constituents with less than reporting limit (non-detectable) results except for *E. coli*, one quarter of the Reporting Limit (RL) was used for calculation and graphing purposes. Reporting limits can vary depending on the dilution factor, EPA method, and/or laboratory.

All of the Organics analyzed in the organic chemical scans were omitted in the summary tables because all results were non-detectable or in other words, below reporting limit (RL) with the exception of chloroform, bromodichloromethane, and dibromochloromethane.

The Organics analyzed along with their RLs are listed in Table 3. Reporting limits can vary depending on the dilution factor, EPA method, and/or laboratory. Some reporting limits may exceed water quality evaluation criteria. Not all of the Organics listed in Table 3 have water quality evaluation criteria, which is listed in Appendix F. Not all of the constituents with MUN water quality objectives (Appendix F) were analyzed due to variations within scans provided by each laboratory.

Table 3 Organics and Reporting Limits

Organics	RL (µg/L)	Organics	RL (µg/L)	Organics	RL (µg/L)
1,1,1,2-Tetrachloroethane	0.5	Aldicarb sulfone	2	Ethoprop	0.2
1,1,1-Trichloroethane (TCA)	0.5	Aldrin	0.05	Ethylbenzene	0.5
1,1,2,2-Tetrachloroethane	0.5	alpha-BHC	0.05	Fensulfothion	0.2
1,1,2-Trichloro-1,2,2-trifluoroethane	5	alpha-Chlordane	0.05	Fenthion	0.2
1,1,2-Trichloroethane	0.5	Anthracene	5.3	Fluoranthene	5
1,1-Dichloroethane	0.5	Atrazine	0.5	Fluorene	5
1,1-Dichloropropene	0.5-5	Azinphos methyl	0.2	gamma-Chlordane	0.05
1,2,3-Trichlorobenzene	0.5-5	Benzene	0.5	Heptachlor epoxide	0.05
1,2,3-Trichloropropane (123TCP)	5	Benzidine	5-5.3	Hexachlorobenzene	5-5.3
1,2,4-Trichlorobenzene	5-5.3	Benzo (a) anthracene	5.3	Hexachlorobutadiene	5-5.3
1,2,4-Trimethylbenzene	5	Benzo (a) pyrene	5.3	Hexachlorocyclopentadiene	5-5.3
1,2-dibromo-3-chloropropane (DBCP)	10	Benzo (b) fluoranthene	5.3	Hexachloroethane	50
1,2-Dibromoethane (EDB)	0.5	Benzo (k) fluoranthene	5.3	Indeno(1,2,3-cd)pyrene	5.3
1,2-Dichlorobenzene	0.5-5.3	Benzo(ghi)perylene	5-5.3	Iodomethane	50
1,2-Dichloroethane (1,2-DCA)	0.5	beta-BHC	0.05	Isophorone	0.35
1,2-Dichloropropane	0.5	Bis(2-chloroethoxy)methane	5-5.3	Isopropylbenzene	5
1,2-Diphenylhydrazine	5-5.3	Bis(2-chloroethyl) ether	5.3	m,p-Xylene	0.5
1,3,5-Trimethylbenzene	5	Bis(2-chloroisopropyl)ether	5-5.3	MBAs (foaming agents)	0.06
1,3-Dichlorobenzene	0.5-5.3	Bis(2-ethylhexyl) phthalate	5.3	MCPA	30
1,3-Dichloropropane	0.5-5	Bolstar	0.2	MCPP	30
1,4-Dichlorobenzene	0.5-5.3	Bromobenzene	0.5	Merphos	0.2
2,2-Dichloropropane	0.5-5	Bromochloromethane	0.5	Methiocarb	2
2,3,7,8-TCDD (Dioxin)	5.4	Bromoform	0.5	Methomyl	2
2,4,5-T	0.5	Bromomethane	1.0-2.0	Methoxychlor	0.05
2,4,5-TP (Silvex)	0.5	Butyl benzyl phthalate	5-5.3	Methyl parathion	0.2
2,4,5-Trichlorophenol	5-5.3	Carbaryl	2	Methylene chloride	1
2,4,6-Trichlorophenol	5-5.3	Carbofuran	2	Methyl-tert-Butyl Ether (MTBE)	0.5
2,4-D (2,4-Dichlorophenoxyacetic acid)	5	Carbon disulfide	0.5-50	Mevinphos	0.2
2,4-DB (2,4-Dichlorophenoxybutyric acid)	5	Carbon tetrachloride	0.5	Naled	0.2
2,4-Dichlorophenol	5-5.3	Chlordane	0.1	Naphthalene	5.3
2,4-Dimethylphenol	5.3	Chlorobenzene	0.5	n-butylbenzene	5
2,4-Dinitrophenol	5-5.3	Chloroethane	0.5	Nitrobenzene	5.3
2,4-Dinitrotoluene	5-5.3	Chloromethane	0.5	N-Nitrosodimethylamine	5-5.3
2,6-Dinitrotoluene	5-5.3	Chlorpyrifos	0.02	n-Propylbenzene	5
2-Butanone	20	Chrysene	5.3	o-Xylene	0.5
2-Chloronaphthalene	5-5.3	cis-1,2-Dichloroethene	0.5	PCB-1016	0.5
2-Chlorophenol	5.3	cis-1,3-Dichloropropene	0.5	PCB-1221	0.5
2-Chlorotoluene	0.5-5	Coumaphos	0.2	PCB-1232	0.5
2-Hexanone	20	Dalapon	20	PCB-1242	0.5
2-Methylnaphthalene	5.3	delta-BHC	0.05	PCB-1248	0.5
2-Methylphenol	5-5.3	Demeton O/S	0.2	PCB-1254	0.5
2-Nitroaniline	5-5.3	Diazinon	0.2	PCB-1260	0.5
2-Nitrophenol	5-5.3	Dibenzo(a,h)anthracene	5-5.3	Pentachlorophenol	1.1
3,3'-Dichlorobenzidine	5-5.3	Dibenzofuran	5-5.3	Phenanthrene	5-5.3
3-Hydroxycarbofuran	2	Dibromochloropropane	5	Phenol	5-5.3
3-Methylphenol	5-5.3	Dibromomethane	0.5	Phorate	0.2
3-Nitroaniline	5-5.3	Dicamba	0.5	p-Isopropyltoluene	0.5-5
4,4'-DDD	0.05	Dichlorodifluoromethane	1	Promecarb	2
4,4'-DDE	0.05	Dichloromethane	0.5	Propoxur (Baygon)	2
4,4'-DDT	0.05	Dichloroprop	5	Pyrene	5
4,6-Dinitro-2-methylphenol	5-5.3	Dichlorvos	0.2	Ronnel (Fenchlorphos)	0.2
4-Bromophenyl phenyl ether	5-5.3	Dieldrin	0.05	sec-butylbenzene	5
4-Chloro-3-methylphenol	5-5.3	Diethyl phthalate	5-5.3	Simazine	0.5
4-Chloroaniline	5-5.3	Dimethyl phthalate	5-5.3	Stirophos (Tetrachlorvinphos)	0.2
4-Chlorophenyl phenyl ether	5-5.3	Di-n-butyl phthalate	5-5.3	Styrene	5
4-Chlorotoluene	0.5	Di-n-octyl phthalate	5-5.3	tert-Butylbenzene	5
4-Methyl-2-pentanone	20	Dinoseb	2.5	Tetrachloroethene (PCE)	0.5
4-Methylphenol	5	Dioxacarb	2	Tokuthion (Prothiofos)	0.2
4-Nitroaniline	5-5.3	Diphenylamine	5-5.3	Toluene	0.5
4-Nitrophenol	5-5.3	Disulfoton	0.5	Toxaphene	0.5
Acenaphthene	5.3	Endosulfan I	0.05	trans-1,2-Dichloroethene	0.5
Acenaphthylene	5-5.3	Endosulfan II	0.05	trans-1,3-Dichloropropene	0.5
Acetone	20	Endosulfan sulfate	0.05	Trichloroethene (TCE)	0.5
Acrolein	10	Endrin	0.05	Trichloronate	0.2
Acrylonitrile	5	Endrin aldehyde	0.05	Trifluralin	0.05
Aldicarb	2	Endrin ketone	0.05	Vinyl chloride	0.5

NOTE: The following organics with MUN water quality objectives were not tested due to scan variations with different labs: trichlorfluoromethane; alachlor; bentazon; bis (2-ethylhexyl) adipate; diquat; endothall; ethylene bromide; glyphosate; molinate; oxamyl; picloram; and thibencarb.

Table 4 Summary Results: Colusa Study Area, April 2012—September 2013

		Upstream																								
		520COL006					520COL005					520COL107					520COL106					520COL003				
		Colusa Basin Drain @ HWY 20					Powell Slough @ HWY 20					New Ditch, upstream of effluent					Unnamed Tributary, upstream of effluent					Powell Slough, upstream of effluent				
Constituents	**Evaluation Criteria**	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																										
DO (mg/L)	NA	27	5.5	8.3	8.5	12	27	1.3	4.9	4.9	10	20	3.9	7.8	8.1	14	28	2.5	5.8	6.0	12	31	5.2	7.7	8.3	18
pH	6.5 - 8.5	29	7.37	7.73	7.76	8.18	29	7.33	7.62	7.63	7.95	23	7.16	7.83	7.85	8.37	30	7.10	7.72	7.73	8.63	33	7.05	7.90	7.88	8.66
Water Temperature (°C)	NA	29	8.3	19	18	26	29	7.6	17	17	25	23	6.4	17	17	28	30	6.8	19	17	28	33	7.4	21	18	31
Turbidity	5 NTU	29	20.8	53.5	56.4	160	29	4.1	27.5	35.6	111	24	11.4	42.4	83.1	408	26	5.9	40.7	62.3	216	29	14.1	31.7	47.2	168
Specific Conductivity	900 µS/cm	29	367	495	552	1080	29	482	822	913	2100	23	682	1690	1810	3470	30	111	995	1010	1870	33	399	810	928	2050
Monthly Samples																										
Arsenic - Dissolved	10 µg/L	6	6	8	9	11	6	5	7.6	7.8	12	5	5.8	12	13	19	5	5.5	11	13	25	6	6	8	8.6	11
Arsenic - Total	10 µg/L	12	3.2	4.4	3.4	<10	12	6.1	9.7	6.5	12	10	6.7	12	10	21	11	5.5	12	14	41	12	6.4	<10	6.9	12
Boron	1000 µg/L	16	130	190	213	340	17	150	310	343	600	15	290	950	914	1900	16	210	425	432	720	17	130	360	364	600
Calcium (mg/L)	NA	14	23	31	33	53	14	26	49	45	100	11	25	83	72	150	12	24	45	44	65	14	23	45	49	86
E. coli	235 MPN/100mL	16	46.4	127	187	866	15	24.6	93.4	99.5	192	12	<1.0	22	226	>2419.6	14	10.9	72.3	316	>2419.6	16	6.3	36	61	461
Hardness as CaCO3 (mg/L)	NA	15	120	180	180	300	15	150	260	280	570	12	140	410	450	710	13	140	260	260	420	15	130	250	280	540
Magnesium (mg/L)	NA	14	16	22	23.0	42.0	14	19	35	39	78	11	19	56	60	95	12	19	36	37	63	14	17	35	41	80
Nitrate as N	10 mg/L	17	0.12	0.28	0.29	0.84	17	0.06	<0.2	0.2	0.7	14	<0.05	1.2	1.4	7.5	15	<0.11	0.23	0.21	<1.1	17	<0.05	0.3	0.2	<1
Sodium	20 mg/L	18	33	48	59	140	18	48	99	129	433	15	110	300	373	750	16	80	137	161	306	18	38	105	141	446
Sulfate	250 mg/L	12	17	52	59	160	12	37	94	163	630	9	200	570	663	1300	10	42	135	158	390	12	42	97	183	570
Total Dissolved Solids	500 mg/L	12	240	295	331	640	12	330	490	598	1400	9	200	570	663	1300	10	450	620	691	1100	12	390	500	644	1300
Quarterly Samples																										
Aluminum - Dissolved	200 µg/L	5	<5.0	6.7	5.9	<50	5	<5.0	<5.0	3.5	<50	4	<5.0	<5.0	<5.0	<5.0	5	<5.0	16	13	<50	5	<5.0	<5.0	3.5	<50
Aluminum - Total	200 µg/L	10	721	2150	2100	3900	10	120	759	1420	4800	9	640	2700	2640	6180	10	298	1360	2520	8120	10	357	1030	1430	3830
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	4	<0.5	<0.5	0.2	0.6	5	<0.5	<0.5	0.5	<5	5	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	5	91	110	110	140	5	76	110	104	120	4	74	83	82	87	5	65	75	76	83	5	77	82	90	130
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	4	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	<0.1	<1	5	<0.3	<0.3	0.1	<1	4	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1
Chloride	250 mg/L	12	11	18	21	56	12	13	27	34	87	9	62	120	114	160	10	15	48	47	75	12	13	30	42	100
Chromium - Total	50 µg/L	5	3	8	7	10	5	2.4	5.4	6.6	13	4	2	6	6	9	5	1.4	5.9	5.4	11	5	2.5	3.8	3.6	7.6
Copper - Total	1000 µg/L	5	5.2	6.8	7.1	9.5	5	4.1	6.6	6.9	11	4	6.3	8.1	8.4	11	5	3.4	8.1	7.0	11	5	3.8	4.4	4.3	7.8
Fluoride	2.0 mg/L	9	0.21	0.29	0.32	0.43	9	0.32	0.43	0.48	0.76	7	0.32	0.52	0.61	1.1	8	0.29	0.43	0.50	0.78	9	0.33	0.43	0.48	0.73
Iron - Dissolved	300 µg/L	5	24	46	66	130	5	10	17	18	30	4	<10	<10	8.5	19	5	21	42	39	62	5	<10	13	13	25
Iron - Total	300 µg/L	10	1170	3260	3180	6600	10	370	1200	2140	7400	9	557	2800	3050	5500	10	437	1900	3280	8490	10	565	1600	2040	4700
Lead - Total	15 µg/L	5	0.52	1.2	1.0	1.7	5	0.62	1.2	1.2	1.8	4	0.32	1.1	1.5	3.3	5	0.39	1.2	1.3	3.1	5	1.0	<1.0	0.9	1.7
Manganese - Dissolved	50 µg/L	5	<1	1	0.7	<10	5	<1.0	14	149	650	4	2.4	9.1	103	390	5	3.5	300	252	457	5	<1.0	1.6	39	190
Manganese - Total	50 µg/L	10	120	221	224	380	10	91	355	547	2080	9	119	471	472	910	10	149	470	563	1300	10	137	398	452	1110
Mercury - Total	0.05 µg/L*	5	<0.2	<0.2	0.1	<0.4	5	<0.2	<0.2	0.1	<0.4	4	<0.2	<0.2	0.1	<0.4	5	<0.2	<0.2	0.1	<0.4	5	<0.2	<0.2	0.1	<0.4
Nickel - Total	100 µg/L	5	6.8	8.9	9.6	14	5	6.7	11	12	20	4	7.8	13	12	16	5	6.5	12	11	15	5	6.9	8	8.3	11
Perchlorate	6 µg/L	5	<2	<2	0.6	<4	5	<2	<2	0.6	<4	4	<2	<4	0.9	<4	5	<2	<2	0.6	<4	5	<2	<2	0.9	<8
Selenium - Total	50 µg/L	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	4	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	4.2	<20	5	<1.0	<1.0	4.2	<20
Silver - Total	100 µg/L	5	<0.3	<1	0.4	<50	5	<0.3	<0.1	0.4	<5.0	4	<0.3	<1.0	0.2	<1.0	5	<0.3	<1.0	0.4	<5.0	5	<0.3	<1.0	0.4	<5.0
Thallium - Total	2 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	4	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	<5.0	9.9	9.1	14	5	5.0	8.4	9.6	19	4	<5.0	8.5	8.6	16	5	<5.0	8.8	7.2	15	5	<5.0	5.6	5.0	11
Chloroform	1.8 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5

NOTE: Lab reporting limit for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 4 continued: Summary Results: Colusa Study Area, April 2012—September 2013

		Effluent					Downstream														
							520COL105					520COL102					520COL101				
		Colusa Effluent					Unnamed Tributary, downstream of effluent					Powell Slough, downstream of effluent					Colusa Basin Drain @ Abel Road				
Constituents	**Evaluation Criteria**	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																					
DO (mg/L)	NA	25	4.1	8.2	8.3	12	30	3.7	7.5	7.4	13	29	5.7	8.5	9.0	19	28	5.5	7.5	8.1	12
pH	6.5 - 8.5	33	6.90	7.47	7.46	7.85	31	7.06	7.80	7.77	8.4	33	7.09	7.88	7.91	8.90	30	7.14	7.79	7.84	8.25
Water Temperature (°C)	NA	33	14	22	23	59	32	6	21	19	29	33	7.2	20	19	35	30	7.7	20	18	26
Turbidity	5 NTU	31	0.4	1	1	5	28	5	29	35	134	29	22	37	47	172	30	7.8	49	56	217
Specific Conductivity	900 µS/cm	28	807	903	903	1020	32	640	975	1060	2480	33	386	891	947	1640	30	306	546	568	1140
Monthly Samples																					
Ammonia as N	1.5 mg/L	1	<1.0	<1.0	<1.0	<1.0															
Arsenic - Dissolved	10 µg/L	6	1.3	1.7	2.0	3.0	6	3.3	5.7	6.4	11	7	3.0	8.1	7.0	9.5	6	2.4	3.3	3.5	6.2
Arsenic - Total	10 µg/L	12	1.3	3.3	2.5	<10	12	3.6	9.6	6.6	13	12	4.8	9.9	6.6	11	12	3.4	4.9	3.9	<10
Boron	1000 µg/L	18	130	213	234	410	17	260	440	472	850	17	140	410	397	730	18	130	213	234	410
Calcium (mg/L)	NA	15	14	17	17	21	14	14	36	33	79	14	24	43	46	87	14	14	23	24	46
E. coli	235 MPN/100mL	16	<1.0	<1.0	<1.0	<1.0	15	4.1	18	190	>2419.6	16	11	39	214	>2419.6	16	30	100	140	370
Hardness as CaCO3 (mg/L)	NA	16	66	87	86	110	15	69	210	190	480	15	130	240	270	550	15	110	170	180	340
Magnesium (mg/L)	NA	15	12	87	11	13	14	7.6	30	26	68	14	17	33	38	81	14	14	23	24	46
Nitrate as N	10 mg/L	17	21	26	27	31	17	1.8	11	12	27	17	<0.44	1.4	2.4	6.8	17	<0.11	0.29	0.28	0.58
Sodium	20 mg/L	18	28	53	65	150	18	98	150	180	440	18	39	120	160	390	18	28	53	65	150
Sulfate	250 mg/L	12	19	51	69	200	12	35	80	150	740	12	40	110	190	610	12	19	51	69	200
Total Dissolved Solids	500 mg/L	12	200	315	347	720	12	500	606	708	1700	12	420	535	669	1400	12	200	315	347	720
Quarterly Samples																					
Aluminum - Dissolved	200 µg/L	5	8.7	14	13	<50	5	<5.0	6.2	7.0	<50	5.0	<5.0	<5.0	3.5	<50	5	<5.0	<5.0	13	<50
Aluminum - Total	200 µg/L	10	17	50	20	55	10	188	585	804	3110	10	363	960	1350	4800	10	453	1850	1950	3670
Antimony - Total	6 µg/L	6	<0.5	<0.5	0.3	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	6	32	39	38	42	5	34	51	49	60	5	63	75	82	120	5	91	99	110	130
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	6	<0.2	<0.3	0.1	<1	5	<0.2	<0.3	0.1	<1	5	<0.2	<0.3	0.1	<1	5	<0.3	<0.3	0.4	<1
Chloride	250 mg/L	12	12	18	22	56	12	26	67	68	110	12	15	40	48	94	12	12	18	22	56
Chromium - Total	50 µg/L	6	<0.5	0.5	0.5	<5	5	0.6	2.1	1.6	<5	5	2.1	11	4.4	4.2	5	4.0	5.4	5.7	9.2
Copper - Total	1000 µg/L	6	4.4	5.7	5.9	11	5	3.9	5.0	4.6	6.7	5	3.7	10	5.1	5.1	5	4.6	5.8	5.5	8.5
Fluoride	2.0 mg/L	9	0.26	0.30	0.34	0.51	9	0.28	0.57	0.54	0.75	9	0.33	0.46	0.73	2.7	9	0.26	0.3	0.34	0.51
Iron - Dissolved	300 µg/L	5	20	29	33	57	5	<10	30	37	92	5	<10	16	45	180	5	30	47	51	96
Iron - Total	300 µg/L	10	<20	32	41	95	10	257	919	998	2790	10	576	6700	1480	1900	10	745	2950	2840	5900
Lead - Total	15 µg/L	6	0.11	0.34	0.26	<1.0	10	257	919	998	2790	5	0.5	2.4	<1.0	1.0	5	0.68	0.94	0.80	1.5
Manganese - Dissolved	50 µg/L	5	<1.0	<1.0	1.4	<10	5	1.4	23	69	180	5	<1.0	1.2	31	150	5	<1.0	1.5	1.5	<10
Manganese - Total	50 µg/L	10	<1	4	2	<10	10	35	170	160	310	10	130	810	260	340	10	150	190	220	390
Mercury - Total	0.05 µg/L*	5	<0.2	<0.2	0.1	<0.4	5	<0.2	<0.2	0.1	<0.4	5	<0.2	<0.4	<0.2	0.1	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	6	1.2	1.8	1.6	<5.0	5	3.7	<5.0	4.2	6.0	5	6.4	15	7.3	8.6	5	5.5	8.2	8.6	13
Perchlorate	6 µg/L	5	<1	<2	0.6	<4	5	<4.0	<20	4.4	<40	5	<2	<2	0.6	<4	5	<1	<2	0.6	<4
Selenium - Total	50 µg/L	6	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	4.2	<20	5	<1.0	<20	<1.0	1.2	5	<1.0	<1.0	1.2	<20
Silver - Total	100 µg/L	6	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	5	<0.3	<5	<1	0.4	5	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	6	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	6	28	35	34	38	5	15	27	24	29	5	<5.0	19	9.7	9.5	5	6.6	8.5	8.6	12
Chloroform	1.8 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5

NOTE: Lab reporting limit for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 5 Summary Results: Willows Study Area, April 2012—September 2013

		Upstream															Effluent				
		520GEL005					520GEL001					520GEL002									
	Evaluation	Ag Drain C, 1500 ft upstream of effluent					Willow Creek at Road 61					Colusa Basin Drain at Road 61					Willows Effluent				
Constituents	Criteria	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																					
DO (mg/L)	NA	31	3.9	9.6	10	17	27	4.4	8.3	8.7	13	27	6.5	8.8	8.9	13	27	7.7	8.8	9.2	12
pH	6.5 - 8.5	33	6.49	7.91	7.90	8.55	29	7.43	7.70	7.77	8.09	29	7.34	7.77	7.76	8.18	33	6.88	7.53	7.53	7.94
Water Temperature (°C)	NA	33	7.8	18	17	26	29	7.4	18	17	24	29	7.9	18	17	27	33	10	22	21	29
Turbidity	5 NTU	33	6.9	24	39	410	29	9.4	24	53	600	29	18	43	48	150	33	0.22	0.84	0.93	2.1
Specific Conductivity	900 µS/cm	33	237	550	578	1240	29	219	369	389	602	29	292	461	478	661	33	744	859	882	1690
Monthly Samples																					
Ammonia as N	0.035 mg/L																1	<1.0	<1.0	<1.0	<1.0
Arsenic - Dissolved	10 µg/L	6	1.6	2.0	2.0	2.5	6	2.0	2.5	2.5	3.2	6	2.8	3.5	3.6	4.8	5	1.5	2.0	1.9	2.2
Arsenic - Total	10 µg/L	12	1.9	2.7	2.5	<10	12	2.9	3.3	2.9	<10	12	3.3	4.9	3.8	<10	6	1.6	2.1	2.1	<10
Boron	1000 µg/L	11	100	210	200	260	11	69	100	100	130	11	88	130	130	180	1	220	250	260	320
Calcium (mg/L)	NA	14	15	34	32	46	14	23	31	34	55	14	23	34	37	59	14	23	33	32	37
E. coli	235 MPN/100mL	16	16.1	144	252	1120	16	28.2	118	176	980	16	34.5	126	129	299	16	<1.0	<1.0	<1.0	<1.0
Hardess as CaCO3 (mg/L)	NA	15	95	200	190	270	15	130.0	160	190	310	15	140	210	220	330	15	160	200	200	220
Magnesium (mg/L)	NA	14	14	26	26	36	14	16	21	24	42	14	18	29	29	47	14	26	28	28	30.
Nitrate as N	10 mg/L	17	0.29	0.83	0.98	2.2	17	0.11	<0.22	0.21	0.95	17	<0.11	<0.22	0.19	0.50	13	12	20	20	45
Sodium	20 mg/L	18	21	53	60	140	18	11	19	21	45	18	15	21	25	61	5	83	105	110	250
Sulfate	250 mg/L	12	25	39	42	65	12	7	10	10	20	12	6	10	10	20	18	58	91	85	120
Total Dissolved Solids	500 mg/L	12	260	350	349	420	12	180	226	242	340	12	230	260	278	440	13	490	540	529	570
Quarterly Samples																					
Aluminum - Dissolved	200 µg/L	5	<5.0	7.5	6.5	<50	5	<5.0	5.0	4.7	<50	5	<5.0	5.8	6.7	<50	2	9.9	11	11	<50
Aluminum - Total	200 µg/L	10	436	662	714	1200	10	250	560	692	1300	10	398	1300	1380	2630	5	13	38	28	130
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	10	<0.5	0.6	0.4	<5
Barium - Total	1000 µg/L	5	79	89	94	120	5	110	130	130	180	5	140	170	180	260	12	65	82	80	89
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	6	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.2	<0.3	0.1	<1
Chloride	250 mg/L	12	5.3	11	11	16	12	3.2	6.3	6.2	10	12	5.0	7.0	7.0	11	11	45	55	55	64
Chromium - Total	50 µg/L	5	1.5	2.6	2.3	<5.0	5	1.5	3.9	2.5	<5.0	5	2.4	<5.0	4.6	7.6	6	1.6	1.9	1.7	<5.0
Copper - Total	1000 µg/L	5	1.5	3.5	2.7	<5.0	5	2.2	4.1	2.9	<5.0	5	2.9	5.7	4.8	8	6	3.8	<5.0	4.3	6.4
Fluoride	2.0 mg/L	5	0.34	0.45	0.47	0.60	5	0.14	0.18	0.18	0.24	5	0.17	0.26	0.25	0.35	13	0.37	0.42	0.43	0.50
Iron - Dissolved	300 µg/L	5	13.0	14.0	30.3	60.6	5	<10.0	37.0	37.7	61.0	5	<10.0	57.4	54.2	94.0	6	<10.0	15.0	15.4	28.6
Iron - Total	300 µg/L	10	570	1080	1100	1700	10	545	1110	1160	2200	10	756	2000	2380	4600	10	19	21	25	<100
Lead - Total	15 µg/L	5	0.2	0.3	0.3	<1	5	0.3	0.6	0.4	<1	5	0.4	0.9	0.7	<2	6	<0.1	0.1	0.1	<1
Manganese - Dissolved	50 µg/L	5	<1.0	15	17	42	5	<1.0	1.1	57	160	5	<1.0	39	35	74	5	<1	<1	0.7	<10
Manganese - Total	50 µg/L	10	47	80	85	130	10	93	140	160	240	10	120	300	300	450	10	<1.0	3.2	4.9	38
Mercury - Total	0.05 µg/L*	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	2.5	4.7	3.2	5.1	5	3.4	6.0	5.8	7.8	5	4.6	9.2	9.1	13	6	1.3	1.7	1.5	<5.0
Perchlorate	6 µg/L	5	<2	<2	0.7	<4	5	<2	<2	0.7	<4	5	<2	<2	0.7	<4	6	<2	<20	5.3	<40
Selenium - Total	50 µg/L	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	6	<1.0	<1.0	1.0	<20
Silver - Total	100 µg/L	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	6	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	6	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	<5.0	<5.0	<5.0	<5.0	5	<5.0	<5.0	2.1	5.6	5	3.9	6.0	6.8	10	6	21	32	31	47
Chloroform	1.8 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	9	4.6	47	40	50
Bromodichloromethane	0.56 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	9	1.3	14	13	17
Dibromochloromethane	0.41 µg/L	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	9	<0.5	2.6	2.1	2.9

NOTE: Lab reporting limit for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 5 continued: Summary Results: Willows Study Area, April 2012—September 2013

		Downstream																			
		520GEL004					520GEL003					520COL109					520COL108				
	Evaluation	Ag Drain C, 100 ft downstream					Ag Drain C at Road 60					Logan Creek, downstream of effluent					Hunters Creek*				
Constituents	**Criteria**	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																					
DO (mg/L)	NA	31	4.0	10	10	16	27	4.9	8.1	8.9	16	27	6.0	8.4	8.4	13	27	7.7	10	10	15
pH	6.5 - 8.5	33	7.55	8.01	8.02	8.52	29	7.39	7.75	7.82	8.32	29	7.20	7.61	7.72	9.26	29	7.04	7.76	7.78	8.30
Water Temperature (°C)	NA	33	8.1	19	18	27	29	7.8	17	17	27	29	7.9	20	18	28	29	7.2	20	18	27
Turbidity	5 NTU	33	7.4	21	34	370	29	8.1	35	51	400	29	10	27	36	100	29	13	29	58	480
Specific Conductivity	900 µS/cm	33	272	573	586	1390	29	115	508	498	822	29	279	397	435	855	29	190	346	378	868
Monthly Samples																					
Arsenic - Dissolved	10 µg/L	6	1.7	2.0	2.1	2.6	6	1.4	2.0	2.2	2.9	6	1.9	2.6	2.6	3.1	6	1.4	1.9	1.9	2.6
Arsenic - Total	10 µg/L	12	1.8	2.7	2.4	<10	12	2.3	3.2	2.7	<10	12	2.6	3.8	3.1	<10	12	1.8	2.5	2.4	<10
Boron	1000 µg/L	11	100	210	197	260	11	120	210	208	270	11	124	193	197	300	11	95	140	135	203
Calcium (mg/L)	14	14	16	30.	30.	39	14	15	26	26	36	14	15	22	22	34	14	15	23	22	35
E. coli	235 MPN/100mL	16	16.1	144	252	1120	16	26.5	151	346	>2419.6	16	36	56	69	130	16	23	120	160	820
Hardess as CaCO3 (mg/L)	NA	15	98.0	170	170	230	15	78.0	160	160	230	15	91	120	140	220	15	71	110	110	170
Magnesium (mg/L)	NA	14	14.0	24	25	33	14	10.	23	22	33.0	14	13	17	18	32	14	8.1	13	13	21
Nitrate as N	10 mg/L	17	1.3	2.4	3.1	8.0	17	0.14	1.2	1.4	3.6	17	<0.11	<0.22	0.24	0.60	17	0.11	<0.22	0.26	0.72
Sodium	20 mg/L	18	21	53	60	140	18	21	51	56	150	18	27	42	54	120	18	15	33	43	160
Sulfate	250 mg/L	12	25	39	42	65	12	10	56	48	94	12	16	29	45	140	12	12	21	26	60
Total Dissolved Solids	500 mg/L	12	260	350	349	420	12	130	319	298	440	12	160	221	261	520	12	120	190	204	340
Quarterly Samples																					
Aluminum - Dissolved	200 µg/L	5	<5.0	8.7	7.1	<50	5	2.5	9.1	7.3	<50	5	5.7	8.9	9.3	<50	5	<5.0	12	10	<50
Aluminum - Total	200 µg/L	10	353	606	678	1300	10	259	1280	1630	4040	10	229	615	1070	2800	10	276	888	1390	4500
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	5	75	79	82	100	5	50	87	81	94	5	54	61	66	80	5	46	56	68	110
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1
Chloride	250 mg/L	12	5.3	11	11	16	12	3.1	11	11	17	12	4.8	8.2	9.2	22	12	5.5	12	15	39
Chromium - Total	50 µg/L	5	2	3	2	<5	5	2	6	6	10	5	1	5	3	8	5	1	3	3	9
Copper - Total	1000 µg/L	5	2	<5	3	5	5	4	6	6	9	5	3	<5	4	8	5	3	4	5	13
Fluoride	2.0 mg/L	5	0.34	0.45	0.47	0.60	5	0.32	0.39	0.40	0.48	5	0.18	0.33	0.31	0.45	5	0.14	0.24	0.24	0.36
Iron - Dissolved	300 µg/L	5	10	16	25	46	5	13	43	42	82	5	78	130	130	220	5	19	38	100	360
Iron - Total	300 µg/L	10	490	957	1040	1800	10	1100	1650	2540	5350	10	614	1330	2090	4900	10	644	1250	2420	9200
Lead - Total	15 µg/L	5	0.2	0.4	0.4	<1	5	0.4	1	0.9	1	5	0.4	1	0.7	1	5	0.3	0.5	0.8	2
Manganese - Dissolved	50 µg/L	5	1.3	14	13	30	5	1.0	4.3	13	33	5	<1.0	3.7	11	40	5	<1.0	2.2	11	36
Manganese - Total	50 µg/L	10	43	68	71	100	10	97	170	180	300	10	83	130	180	320	10	55	86	120	300
Mercury - Total	0.05 µg/L*	5	<0.2	<0.2	0.08	0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	2.4	4.7	3.2	<5.0	5	4.0	7.2	7.1	12	5	4.2	<5.0	5.1	9.1	5	2.8	3.3	4.5	12
Perchlorate	6 µg/L	5	<2	<2	0.7	<4	5	<2	<2	0.7	<4	5	<2	<2	0.6	<4	5	<2	<2	0.6	<4
Selenium - Total	50 µg/L	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20
Silver - Total	100 µg/L	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	5.3	5.7	7.0	12	5	<5.0	8.7	8.9	16	5	<5.0	5.9	5.8	14	5	<5.0	<5.0	3.8	14
Chloroform	1.8 µg/L	9	<0.5	<0.5	0.6	1.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	9	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	9	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5

NOTE:

Hunters Creek receives no effluent and is only a comparison site.

Lab reporting limit for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 6 Summary Results: Live Oak Study Area, April 2012—September 2013

		Upstream										Effluent				
		520SUT008					520SUT006									
	Evaluation	Lateral Drain #2, upstream of effluent					Sutter Bypass, upstream of effluent					Live Oak Effluent				
Constituents	Criteria	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/month)																
DO (mg/L)	NA	26	1.7	9.8	9.9	25	27	6.1	7.5	8.2	11	31	6.3	7.7	8.1	11
pH	6.5 - 8.5	28	7.07	7.72	7.81	8.59	29	7.36	7.74	7.76	8.46	32	7.02	7.25	7.34	8.95
Water Temperature (°C)	NA	28	12	22	21	31	29	8.0	21	19	29	33	17	24	23	29
Turbidity	5 NTU	28	1.0	7.1	25	241	29	9.2	16	21	63	33	0.2	0.7	0.8	2
Specific Conductivity	900 µS/cm	28	526	812	808	1150	29	143	281	293	777	33	719	816	814	941
Monthly Samples																
Ammonia as N	1.5 mg/L											1	<1.0	<1.0	<1.0	<1.0
Arsenic - Dissolved	10 µg/L	12	3.9	23	19	37	11	2.1	3.0	3.3	4.8	12	16	25	25	39
Arsenic - Total	10 µg/L	18	3.8	21	19	40	17	2.2	4.5	3.6	10	18	9.3	25	24	40
Boron	1000 µg/L	12	41	120	110	210	12	26	<50	35	74	12	110	144	151	210
Calcium (mg/L)	NA	13	31	40.	47	74	13	11	23	23	28	14	31	37	38	44
E. coli	235 MPN/100mL	15	6.3	36	51	170	16	8.5	31	38	79	15	<1.0	<1.0	<1.0	<1.0
Hardness as CaCO3 (mg/L)	NA	15	200.0	260	280	430	15	57	120	110	150	16	200	240	250	280
Magnesium (mg/L)	NA	13	30.	40.	43	60.	13	7.1	15	15	19	14	30.	36	37	43
Nitrate as N	10 mg/L	18	<0.22	14	12	19	16	<0.1	<0.2	0.09	0.2	18	10	17	16	20
Sodium	20 mg/L	18	12	63	59	146	17	7	16	17	30	18	51	65	72	160
Sulfate	250 mg/L	12	9	44	46	72	11	3	5	6	10	13	36	41	41	47
Total Dissolved Solids	500 mg/L	12	160	505	486	570	11	120	180	177	210	13	450	500	509	570
Quarterly Samples																
Aluminum - Dissolved	200 µg/L	5	2.9	7.1	8.4	<50	5	<5.0	8.3	9.4	<50	5	<5.0	8.3	9.7	<50
Aluminum - Total	200 µg/L	10	26	200	595	3760	10	230	560	722	1870	10	22.0	40.2	44.3	83.6
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	6	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	5	17	35	68	150	5	53	62	64	74	6	14	28	28	36
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	6	<0.3	<0.3	0.1	<1
Chloride	250 mg/L	12	5	60	50	66	11	5	8	8	11	13	48	60	60	75
Chromium - Total	50 µg/L	5	0.9	2	2	<5	5	1	2	2	<5	6	0.6	0.7	0.9	<5
Copper - Total	1000 µg/L	5	1.2	3.5	3.5	5.6	5	2.1	3.1	2.5	<5.0	6	2.5	3.3	3.6	6.5
Fluoride	2.0 mg/L	5	<0.1	<0.1	0.07	0.1	5	<0.1	0.1	0.06	0.1	6	<0.1	0.1	0.09	0.1
Iron - Dissolved	300 µg/L	4	<10.0	10.0	11.0	29.0	5	12.0	54.0	42.4	62.0	5	<10.0	13.0	17.9	48.3
Iron - Total	300 µg/L	10	69	240	770	4700	10	361	880	969	2150	10	16	38	43	120
Lead - Total	15 µg/L	5	<0.1	<0.1	0.2	0.5	5	0.3	0.4	0.4	<1	6	<0.1	<0.1	0.1	<1
Manganese - Dissolved	50 µg/L	5	3.7	89	130	530	5	<1.0	<1.0	6.5	31	5	<1.0	<1.0	0.7	<10
Manganese - Total	50 µg/L	10	<0.2	<0.2	<0.2	<0.2	10	59	90	106	210	10	0.64	2.6	5.9	23
Mercury - Total	0.05 µg/L*	5	2.3	2.6	2.7	5.1	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	<2.0	<4.0	3.4	<40	5	3.6	4.3	3.6	5.0	6	1.7	2.2	1.9	<5.0
Perchlorate	6 µg/L	5	<1.0	<1.0	1.2	<20	5	<2	<2	0.6	<4	5	<2.0	<20	4.3	<40
Selenium - Total	50 µg/L	5	<0.3	<1	0.4	<5	5	<1.0	<1.0	1.2	<20	6	<1.0	<1.0	1.0	<20
Silver - Total	100 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<0.3	<1	0.4	<5	6	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	1	67	67	67	67	5	<1.0	<1.0	<1.0	<1.0	6	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	<5.0	18	13	22	5	2.6	<5.0	1.5	<5.0	6	18	21	21	25
Chloroform	1.8 µg/L	5	<0.1	8	<0.5	2	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5

NOTE: Lab reporting limit for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 6 continued: Summary Results: Live Oak Study Area, April 2012—September 2013

		Upstream										Effluent				
		520SUT008					520SUT006									
	Evaluation	Lateral Drain #2, upstream of effluent					Sutter Bypass, upstream of effluent					Live Oak Effluent				
Constituents	Criteria	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/month)																
DO (mg/L)	NA	26	1.7	9.8	9.9	25	27	6.1	7.5	8.2	11	31	6.3	7.7	8.1	11
pH	6.5 - 8.5	28	7.07	7.72	7.81	8.59	29	7.36	7.74	7.76	8.46	32	7.02	7.25	7.34	8.95
Water Temperature (°C)	NA	28	12	22	21	31	29	8.0	21	19	29	33	17	24	23	29
Turbidity	5 NTU	28	1.0	7.1	25	241	29	9.2	16	21	63	33	0.2	0.7	0.8	2
Specific Conductivity	900 µS/cm	28	526	812	808	1150	29	143	281	293	777	33	719	816	814	941
Monthly Samples																
Ammonia as N	1.5 mg/L											1	<1.0	<1.0	<1.0	<1.0
Arsenic - Dissolved	10 µg/L	12	3.9	23	19	37	11	2.1	3.0	3.3	4.8	12	16	25	25	39
Arsenic - Total	10 µg/L	18	3.8	21	19	40	17	2.2	4.5	3.6	10	18	9.3	25	24	40
Boron	1000 µg/L	12	41	120	110	210	12	26	<50	35	74	12	110	144	151	210
Calcium (mg/L)	NA	13	31	40.	47	74	13	11	23	23	28	14	31	37	38	44
E. coli	235 MPN/100mL	15	6.3	36	51	170	16	8.5	31	38	79	15	<1.0	<1.0	<1.0	<1.0
Hardness as CaCO3 (mg/L)	NA	15	200.0	260	280	430	15	57	120	110	150	16	200	240	250	280
Magnesium (mg/L)	NA	13	30.	40.	43	60.	13	7.1	15	15	19	14	30.	36	37	43
Nitrate as N	10 mg/L	18	<0.22	14	12	19	16	<0.1	<0.2	0.09	0.2	18	10	17	16	20
Sodium	20 mg/L	18	12	63	59	146	17	7	16	17	30	18	51	65	72	160
Sulfate	250 mg/L	12	9	44	46	72	11	3	5	6	10	13	36	41	41	47
Total Dissolved Solids	500 mg/L	12	160	505	486	570	11	120	180	177	210	13	450	500	509	570
Quarterly Samples																
Aluminum - Dissolved	200 µg/L	5	2.9	7.1	8.4	<50	5	<5.0	8.3	9.4	<50	5	<5.0	8.3	9.7	<50
Aluminum - Total	200 µg/L	10	26	200	595	3760	10	230	560	722	1870	10	22.0	40.2	44.3	83.6
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	6	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	5	17	35	68	150	5	53	62	64	74	6	14	28	28	36
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	6	<0.3	<0.3	0.1	<1
Chloride	250 mg/L	12	5	60	50	66	11	5	8	8	11	13	48	60	60	75
Chromium - Total	50 µg/L	5	0.9	2	2	<5	5	1	2	2	<5	6	0.6	0.7	0.9	<5
Copper - Total	1000 µg/L	5	1.2	3.5	3.5	5.6	5	2.1	3.1	2.5	<5.0	6	2.5	3.3	3.6	6.5
Fluoride	2.0 mg/L	5	<0.1	<0.1	0.07	0.1	5	<0.1	0.1	0.06	0.1	6	<0.1	0.1	0.09	0.1
Iron - Dissolved	300 µg/L	4	<10.0	10.0	11.0	29.0	5	12.0	54.0	42.4	62.0	5	<10.0	13.0	17.9	48.3
Iron - Total	300 µg/L	10	69	240	770	4700	10	361	880	969	2150	10	16	38	43	120
Lead - Total	15 µg/L	5	<0.1	<0.1	0.2	0.5	5	0.3	0.4	0.4	<1	6	<0.1	<0.1	0.1	<1
Manganese - Dissolved	50 µg/L	5	3.7	89	130	530	5	<1.0	<1.0	6.5	31	5	<1.0	<1.0	0.7	<10
Manganese - Total	50 µg/L	10	<0.2	<0.2	<0.2	<0.2	10	59	90	106	210	10	0.64	2.6	5.9	23
Mercury - Total	0.05 µg/L*	5	2.3	2.6	2.7	5.1	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	<2.0	<4.0	3.4	<40	5	3.6	4.3	3.6	5.0	6	1.7	2.2	1.9	<5.0
Perchlorate	6 µg/L	5	<1.0	<1.0	1.2	<20	5	<2	<2	0.6	<4	5	<2.0	<20	4.3	<40
Selenium - Total	50 µg/L	5	<0.3	<1	0.4	<5	5	<1.0	<1.0	1.2	<20	6	<1.0	<1.0	1.0	<20
Silver - Total	100 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<0.3	<1	0.4	<5	6	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	1	67	67	67	67	5	<1.0	<1.0	<1.0	<1.0	6	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	<5.0	18	13	22	5	2.6	<5.0	1.5	<5.0	6	18	21	21	25
Chloroform	1.8 µg/L	5	<0.1	8	<0.5	2	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5

NOTE: Laboratory reporting limits for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 7 Summary Results: Biggs Study Area, April 2012—September 2013

		Upstream															Effluent				
		520BUT902					520BUT004					520BUT002									
	Evaluation	Butte Creek, upstream near Nelson Road					Lateral K, 100 ft upstream of effluent					Cherokee Canal, upstream of effluent					Biggs Effluent				
Constituents	Criteria	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																					
DO (mg/L)	NA	26	7.7	10	11	15	29	1.8	7.9	7.9	13	27	3.0	7.8	8.2	14	26	5.4	8.2	8.1	11
pH	6.5 - 8.5	28	7.37	7.80	7.82	8.35	32	6.80	7.43	7.40	7.86	29	7.16	7.64	7.65	8.34	33	7.08	7.38	7.39	7.60
Water Temperature (°C)	NA	28	5.7	16	14	22	29	6.9	17	16	23	29	6.8	19	17	27	30	9.0	18	17	26
Turbidity	5 NTU	28	1.7	3.2	4.0	20	31	6.9	19	27	113	29	1.8	11	22	92	31	6.1	32	39	98
Specific Conductivity	900 µS/cm	28	81	110	120	210	29	90	210	240	502	29	109	203	242	460	29	240	796	722	900
Monthly Samples																					
Ammonia as N	1.5 mg/L	12	<0.1	<0.1	0.1	<1	12	<0.1	0.2	0.2	1	12	<0.1	<0.1	0.4	4	13	4.9	11	10	14
Arsenic - Dissolved	10 µg/L	12	0.3	0.5	0.8	<10	12	0.9	3	2	<10	12	1.0	1.8	1.9	<10	12	2.6	3.5	3.3	<10
Arsenic - Total	10 µg/L	17	0.3	0.7	0.9	<10	18	1.3	3.3	2.7	<10	18	1.0	2.2	2.3	<10	18	2.6	3.7	3.3	<10
Boron	1000 µg/L	11	17	30	19	<50	12	21	37	22	<50	12	14	30	16	<50	12	82	96	100	140
Calcium (mg/L)	NA	13	8.2	11	12	19.0	13	11	16	23	45	13	9	18	22	46	14	37	43	43	47
E. coli	235 MPN/100mL	16	19.9	40.1	50.6	150	16	13.4	105	266	2420	16	10.9	41.0	50.0	138	16	<1.0	24	300	>2419.6
Hardness as CaCO3 (mg/L)	NA	14	35	51	55	96	14	53	79	120	250	14	45	92	110	240	15	210	240	240	270
Magnesium (mg/L)	NA	13	3.6	5.2	6.0	12	13	6.1	11	15	33	13	5.3	10.	13	31	14	28	34	33	36
Nitrate as N	10 mg/L	11	<0.1	0.2	0.07	0.2	12	<0.11	0.24	0.41	1.0	12	<0.10	0.13	0.10	0.29	12	<0.10	0.14	0.11	0.44
Sodium	20 mg/L	17	3	4	4	8	18	4	10	11	24	18	5	9	10	21	18	35	60	64	150
Sulfate	250 mg/L	12	<2.0	2.3	2.0	5.2	12	3.2	6.3	7.9	17	12	3.4	7.2	7.8	15	13	8.5	16	19	36
Total Dissolved Solids	500 mg/L	12	57	79	84	130	12	94	170	180	370	12	99	130	160	280	13	368	460	454	520
Quarterly Samples																					
Aluminum - Dissolved	200 µg/L	5	<5.0	<5.0	3.5	<50	5	<5.0	14	10	<50	5	<5.0	9.2	9.3	<50	5	<5.0	7.3	9.5	<50
Aluminum - Total	200 µg/L	9	56	130	130	220	10	290	469	738	2600	10	110	209	611	1740	10	10	34	13	50
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	6	<0.5	<0.5	0.3	<5
Barium - Total	1000 µg/L	5	5	16	12	16	5	41	71	85	130	5	72	90	95	120	6	70	79	77	82
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	6	<0.2	<0.3	0.1	<1
Chloride	250 mg/L	12	1.0	1.3	1.3	1.7	12	1.5	3.4	6.0	28	12	2.0	3.5	3.7	5.8	13	28	51	53	92
Chromium - Total	50 µg/L	5	<0.5	0.7	0.7	<5	5	1.1	2.0	2.5	6.5	5	0.6	2	2	<5	6	1.3	2.0	1.8	<5.0
Copper - Total	1000 µg/L	5	0.5	0.9	0.8	<5	5	1.4	3.4	3.0	7.2	5	1.2	3.1	2.8	6.0	6	1.3	2.6	2.0	<5.0
Fluoride	2.0 mg/L	5	<0.10	<0.10	<0.10	<0.10	5	<0.1	<0.1	0.07	0.1	5	<0.10	0.11	0.11	0.13	6	<0.10	0.13	0.11	0.15
Iron - Dissolved	300 µg/L	5	<10.0	<10.0	10.3	28.8	5	11.0	19.0	30.4	83.0	5	20.0	58.0	97.1	240	5	33.0	44.2	50.8	75.0
Iron - Total	300 µg/L	9	11	170	160	230	10	300	710	890	2700	10	350	570	1000	3500	10	42	57	210	990
Lead - Total	15 µg/L	5	<0.1	<0.1	0.1	<1	5	0.2	0.3	0.4	<1	5	0.1	0.4	0.4	<1	6	<0.1	<0.1	0.1	<1
Manganese - Dissolved	50 µg/L	5	<1.0	1.1	1.5	<10	5	4.1	59	58	120	5	1.6	5.7	7.8	15	5	3.1	17	16	25
Manganese - Total	50 µg/L	9	7	21	21	37	10	37	160	180	390	10	17	44	74	200	10	17	21	24	37
Mercury - Total	2 µg/L	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	<1	1	0.9	<5	5	3.0	4.3	4.1	8.1	5	2.1	3.7	3.6	7.7	6	1.1	1.8	1.5	<5.0
Perchlorate	6 µg/L	5	<2	<2	0.6	<4	5	<2	<2	0.6	<4	5	<2.0	<2.0	1.0	<10	5	<4.0	<10	4.2	<40
Selenium - Total	50 µg/L	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	6	<1.0	<1.0	1.0	<20
Silver - Total	100 µg/L	5	0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	5	<0.3	<1	0.4	<5	6	<0.3	<1	0.4	<5
Thallium - Total	2 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	6	<1.0	<1.0	<1.0	<1.0
Zinc - Total	5000 µg/L	5	2.4	<5.0	1.5	<5.0	5	<5.0	<5.0	3.4	6.7	5	1.8	<5.0	2.3	5.9	6	2.9	<5.0	2.3	5.7
Chloroform	1.8 µg/L	4	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	10	<0.5	1	2	6
Bromodichloromethane	0.56 µg/L	4	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	10	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	4	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	10	<0.5	<0.5	<0.5	<0.5

NOTE: Laboratory reporting limits for mercury and perchlorate exceeds the evaluation criteria due to dilution factor, EPA method, and/or laboratory.

Table 7 continued: Summary Results: Biggs Study Area, April 2012—September 2013

Constituents	Evaluation Criteria	Downstream														
		520BUT003					520BUT001					520COL104				
		Lateral K, 100ft downstream of effluent					C Main Drain, downstream of effluent					Butte Slough, downstream of effluent at				
		Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max	Count	Min	Median	Mean	Max
Field Samples (2X/Month)																
DO (mg/L)	NA	30	3.3	7.8	7.7	12	27	6.6	8.8	8.8	12	26	3.9	6.9	7.4	11
pH	6.5 - 8.5	33	6.90	7.59	7.49	7.83	29	7.32	7.65	7.71	8.56	28	7.34	7.79	7.82	8.36
Water Temperature (°C)	NA	29	7.6	17	16	24	29	7.2	19	17	26	28	7.4	21	19	30
Turbidity	5 NTU	31	8.0	18	24	75	29	8.8	21	37	176	28	8.6	19	22	47
Specific Conductivity	900 µS/cm	29	142	305	355	629	29	162	229	285	547	28	131	273	280	384
Monthly Samples																
Ammonia as N	1.5 mg/L	12	0.7	2	2	5	12	<0.1	0.1	0.1	<1	12	<0.1	0.1	0.9	8
Arsenic - Dissolved	10 µg/L	12	1.2	2.7	2.4	<10	12	1.7	3.1	3.5	<10	12	2.1	3.6	4.2	<10
Arsenic - Total	10 µg/L	18	1.3	3.0	2.6	<10	18	2.1	3.7	3.6	<10	17	1.9	4.0	3.8	<10
Boron	1000 µg/L	12	29	<50	41	77	12	27	40	24	<50	11	25	49	40	75
Calcium (mg/L)	NA	13	13	22	26	47	13	15	20.	25	49	13	10.	24	22	28
E. coli	235 MPN/100mL	16	27.5	129	258	1120	16	29.2	129	168	326	16	9.6	41	65	290
Hardness as CaCO3 (mg/L)	NA	14	62	110	140	260	14	77	110	130	270	14	52	120	110	150
Magnesium (mg/L)	NA	13	7.4	16	18	35	13	9.8	13	17	35	13	6.4	15	15	20.
Nitrate as N	10 mg/L	12	<0.10	0.27	0.30	0.66	12	<0.10	0.21	0.25	0.55	12	<0.1	0.2	0.09	0.2
Sodium	20 mg/L	18	6	16	21	41	18	7	8	11	22	17	7	15	16	29
Sulfate	250 mg/L	12	3.8	9.7	9.9	17	12	3.9	6.9	8.4	19	12	2.6	5.8	6.0	9.4
Total Dissolved Solids	500 mg/L	12	110	200	230	440	12	92	140	173	340	12	151	170	181	230
Quarterly Samples																
Aluminum - Dissolved	200 µg/L	5	<5.0	<5.0	5.9	<50	5	<5.0	5.0	6.0	<50	5	<5.0	8.3	7.6	<50
Aluminum - Total	200 µg/L	10	120	380	491	1300	10	350	825	1000	2700	9	209	620	730	1660
Antimony - Total	6 µg/L	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5	5	<0.5	<0.5	0.4	<5
Barium - Total	1000 µg/L	5	45	71	77	110	5	43	66	77	120	5	52	64	66	82
Beryllium - Total	4 µg/L	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1	5	<0.5	<0.5	0.2	<1
Cadmium - Total	5 µg/L	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1	5	<0.3	<0.3	0.1	<1
Chloride	250 mg/L	12	4.1	17	16	29	12	1.8	2.9	3.5	6.5	12	4.5	7.3	7.8	12
Chromium - Total	50 µg/L	5	1.2	1.7	2.0	<5.0	5	1.6	3.8	2.9	6.0	5	1.8	2.3	2.1	<5.0
Copper - Total	1000 µg/L	5	1.6	3.1	2.5	<5.0	5	1.5	3.9	3.1	5.3	5	2.0	3.3	2.6	<5.0
Fluoride	2.0 mg/L	5	<0.10	0.13	5.1	25	5	<0.1	0.1	0.08	0.1	5	<0.1	<0.1	0.07	0.1
Iron - Dissolved	300 µg/L	5	22	39	40	73	5	5.3	24	24	38	5	19	72	58	97
Iron - Total	300 µg/L	10	200	574	719	1800	10	421	960	1130	2900	9	321	1100	1130	1700
Lead - Total	15 µg/L	5	<0.1	0.2	0.2	<1	5	0.3	0.7	0.5	<1	5	0.4	0.5	0.4	<1
Manganese - Dissolved	50 µg/L	5	1.5	29	63	220	5	<1.0	3.9	5.1	17	5	<1.0	2.4	35	150
Manganese - Total	50 µg/L	10	38	120	130	300	10	51	99	130	280	9	59	89	150	430
Mercury - Total	2 µg/L	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2	5	<0.2	<0.2	<0.2	<0.2
Nickel - Total	100 µg/L	5	1.8	4.2	3.1	5.2	5	2.3	4.5	4.0	7.8	5	<1.0	4.9	2.9	5.2
Perchlorate	6 µg/L	5	<2.0	<2.0	1.0	<10	5	<2.0	<2.0	1.5	<20	5	<2.0	<2.0	0.6	<4.0
Selenium - Total	50 µg/L	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.2	<20	5	<1.0	<1.0	1.3	<20
Silver - Total	100 µg/L	5	<0.3	<1	0.4	5	5	<0.3	<1	0.4	<5	5	<0.5	<1	0.4	<5
Thallium - Total	2 µg/L	5	<1.0	<1.0	<1.0	<1.0	5	<1.0	<1.0	<1.0	<1.0	5	<1	<1	0.3	<2
Zinc - Total	5000 µg/L	5	2.5	<5.0	2.3	5.4	5	2.7	<5.0	3.5	7.2	5	3.9	<5.0	1.8	<5.0
Chloroform	1.8 µg/L	10	0.4	<0.5	0.9	6.8	5	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	0.56 µg/L	10	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	0.41 µg/L	10	<0.5	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	<0.5

NOTE: Laboratory reporting limits for Mercury exceeds the evaluation criteria.

9.0 MUNICIPAL AND DOMESTIC SUPPLY (MUN) BENEFICIAL USE AND APPLICABLE WATER QUALITY GOALS AND OBJECTIVES

To evaluate whether water quality may be suitable for the MUN beneficial use, data was compared to Maximum Contaminant Levels (MCLs) specified in provisions of Title 22 of the California Code of Regulations, California Toxics Rule (CTR) criteria, and other numeric water quality criteria listed in Appendix F for constituents without a MCL or CTR criteria. For constituents with both a MCL and CTR criteria, the most conservative numeric threshold was selected for water quality evaluation. For constituents without a MCL and CTR criteria, the most appropriate for protecting MUN beneficial use numeric water quality criteria was selected for water quality evaluation.

A comparison of the different evaluation criteria values is summarized in Appendix F. Evaluation criteria values were obtained from the State Water Board's Water Quality Goals database. Table 8 list key constituents and their criteria. Key constituents consists of constituents that were identified in the effluent during the POTW's NPDES permit renewal process at concentrations that may exceed the evaluation criteria for protecting drinking water supplies, constituents of potential concern through ILRP analyses, and constituents that had frequent elevated concentrations detected during monitoring.

Table 8 Key Constituents and Evaluation Criteria

Parameter	Evaluation Criterion	Source
Aluminum - Dissolved*	200 µg/L	California Secondary MCL
Aluminum - Total	200 µg/L	California Secondary MCL
Ammonia as N	1.5 mg/L	Odor threshold (Amoore and Hautala) (a)
Antimony - Total	6 µg/L	California Primary MCL
Arsenic – Dissolved*	10 µg/L	California Primary MCL
Arsenic - Total	10 µg/L	California Primary MCL
Barium - Total	1 mg/L	California Primary MCL
Beryllium - Total	4 µg/L	California Primary MCL
Boron	1000 µg/L	DDW Notification Level for drinking water
Bromodichloromethane	0.56 µg/L	CTR
Bromoform	4.3 µg/L	CTR
Cadmium - Total	5 µg/L	California Primary MCL
Chloride	250 mg/L	California Secondary MCL
Chloroform	1.8 µg/L	Cal/EPA Cancer Potency Factor as a drinking water level (b)
Chromium - Total	50 µg/L	California Primary MCL
Copper - Total	1000 µg/L	California Secondary MCL
Dibromochloromethane	0.41 µg/L	CTR
E. coli	235 MPN/100mL	USEPA Recreational Guideline for Designated Beach Area (upper 75% Confidence Level) (c)
Fluoride	2.0 mg/L	California Primary MCL
Iron - Dissolved*	300 µg/L	California Secondary MCL

Table 8 continued: Key Constituents and Evaluation Criteria

Parameter	Evaluation Criterion	Source
Iron - Total	300 µg/L	California Secondary MCL
Lead - Total	15 µg/L	California Primary MCL
Manganese - Dissolved*	50 µg/L	California Secondary MCL
Manganese - Total	50 µg/L	California Secondary MCL
Mercury - Total	0.05 µg/L	CTR
Nickel - Total	100 µg/L	California Primary MCL
Nitrate as N	10 mg/L	California Primary MCL
Perchlorate	6 µg/L	California Primary MCL
pH	6.5 - 8.5	USEPA Secondary MCL
Selenium - Total	50 µg/L	California Primary MCL
Silver - Total	100 µg/L	California Secondary MCL
Sodium	20000 µg/L	USEPA Drinking Water Advisory for persons on restricted sodium diet
Specific Conductance	900 µmhos/cm	California Secondary MCL
Sulfate	250 mg/L	California Secondary MCL
Thallium - Total	2 µg/L	California Primary MCL
Total Dissolved Solids	500 mg/L	California Secondary MCL
Turbidity	5 NTU	California Secondary MCL (d)
Zinc - Total	5000 µg/L	California Secondary MCL

NOTE:

*****Dissolved aluminum, iron, and manganese do not have evaluation criteria, so they are evaluated against the Secondary MCL of total aluminum, iron, and manganese. Dissolved arsenic does not have an evaluation criterion, so it's evaluated against the Primary MCL of total arsenic.

(a) The Odor threshold is the most appropriate guideline based on the narrative Tastes and Odors water quality objective in the basin plan.

(b) Assumes 70 kg body weight and 2 liters per day drinking water consumption

(c) USEPA Guideline that was promulgated in 1986 and does not reflect current regulations.

(d) Background concentrations can be highly variable. The Basin Plan has a specific water quality objective for turbidity that takes into account the variability of natural turbidity.

10.0 DISCUSSION

The discussion has been organized into two sections. The first section summarizes all the constituents that exceeded criteria to protect Municipal and Domestic Supply (MUN) by area. The second section provides spatial and temporal trends for select constituents with either continuously elevated levels or distinct patterns, separately for the west and east side of the Sacramento River Basin.

10.1 Summary of Exceedances

As documented in summary tables 4-7, some concentrations reported exceeded evaluation criteria at certain sites. These key constituents were selected for further evaluation. Summary exceedance tables for each key constituent are provided in this section. These tables provide a summary for all the constituents reported at elevated levels and include the criteria, total number of samples collected, and number of samples that had exceedences.

Tables are sorted into study areas: Colusa (Table 9), Willows (Table 10), Live Oak (Table 11), and Biggs (Table 12), respectively. For each study area, the sampling sites are arranged from left to right, upstream to downstream. These tables are also arranged by constituent from top to bottom: Total Aluminum, Total Arsenic, Dissolved Arsenic, Total Iron, Dissolved Iron, Total Manganese, Dissolved Manganese, Nitrate as Nitrogen, Sodium, Total Dissolved Solids (TDS), Specific Conductance (SC), Boron, Total Flouride, Sulfate, Ammonia as Nitrogen, Chloroform, Bromodichloromethane, Dibromochloromethane, and *E. coli*.

Although dissolved aluminum, arsenic, iron, and manganese do not have evaluation criteria, they are evaluated against the Secondary MCLs of total aluminum, arsenic, iron, and manganese (300 µg/L, 10 µg/L, 200 µg/L, and 50 µg/L, respectively). The purpose of analyzing dissolved aluminum, arsenic, iron, and manganese results is to provide water quality of conventional water that uses treatments such as filtration.

10.1.1 Colusa Study Area

Table 9 summarizes water quality results for key constituents collected from the Colusa study area.

Of these key constituents, no exceedances were reported for dissolved aluminum, dissolved iron, ammonia as nitrogen, chloroform, bromodichloromethane or dibromochloromethane in the Colusa Study area. Only four constituents had elevated concentrations in the effluent: nitrate as nitrogen, sodium, TDS, and SC. The rate of exceedance for nitrate as nitrogen, sodium, and TDS was 100%. SC had a 61% exceedance rate.

Exceedances for three of those four constituents and a number of others occurred both upstream and downstream of the effluent. In particular, similar to the effluent, sodium criterion was exceeded in 100% of the samples collected and TDS and SC were elevated at several sites.

Criteria for total aluminum, total iron, and total manganese were frequently exceeded in the surrounding water bodies, though not in the effluent. The rate of exceedance for these three constituents in the upstream and downstream sites was 80—100%. Every upstream and downstream site reported with a maximum total aluminum and iron concentrations of >1000 µg/L, while only three upstream sites reported with a maximum total manganese concentration of >1000 µg/L. Highest concentrations of total aluminum, iron, and manganese ranged up to 8120 µg/L at Unnamed Tributary upstream, 8490 µg/L at Unnamed Tributary upstream, and 2080 µg/L at Powell Slough at Hwy 20, respectively (Table 4).

Conversely, only the effluent and first downstream site showed elevated levels of nitrate as nitrogen. Nitrate as nitrogen criteria was not exceeded in any of the upstream sites or two further downstream sites within the study area.

Total arsenic, dissolved manganese, and sulfate, exceeded their criteria of 10 µg/L, 50 µg/L, and 250 mg/L, respectively at more than one site. Dissolved arsenic and *E. coli* was found elevated above its criteria of 10 µg/L and 200 MPN/100mL, respectively at more than one site as well. Colusa is one of the two study areas that had exceedances or elevated levels in total and dissolved arsenic.

Boron was elevated above its criterion of 1000 µg/L only at one site which was New Ditch, upstream of effluent. Total fluoride had also exceeded its criterion of 2 mg/L at only one site (one sample) which was Powell Slough, downstream of effluent.

10.1.2 Willows Study Area

Table 10 summarizes water quality results for key constituents collected from the Willows study area. Hunters Creek receives no effluent and is only a comparison site.

Of these key constituents, no exceedances were reported for total arsenic, dissolved arsenic, boron, total fluoride, or sulfate in the Willows study area. Only five constituents had elevated concentrations in the Willows POTW effluent: nitrate as nitrogen, sodium, TDS, SC, and trihalomethanes. The rate of exceedance for nitrate as nitrogen and sodium was 100%. Conductance and TDS had rates of exceedance of 18% and 85%, respectively. Trihalomethanes had an 89% exceedance rate.

Only the effluent site showed elevated levels of nitrate as nitrogen and trihalomethanes. Both nitrate as nitrogen and trihalomethanes were not exceeded in any of the upstream and downstream sites within the study area.

Exceedances for a number of constituents occurred upstream and/or downstream of the influence of the effluent. In particular, sodium criteria was exceeded in 44—100% of the samples collected in upstream and downstream sites.

Criteria for total aluminum, total iron, and total manganese were frequently exceeded in the surrounding water bodies, though not in the effluent. The rate of exceedance for these three constituents in the upstream and downstream sites was 90—100%. Every upstream and downstream site reported with a maximum total aluminum and iron concentrations of >1000 µg/L, while every upstream and downstream site reported with a maximum total manganese concentration of >100 µg/L. Highest concentrations of total aluminum, iron, and manganese ranged up to 4040 µg/L at Ag Drain C at Road 60, 9200 µg/L at Hunter Creek downstream, and 450 µg/L at Colusa Basin Drain at Road 61, respectively (Table 5).

E. coli was found elevated above its criterion of 200MPN/100mL for all sites except for the Willows effluent and Logan Creek, downstream of effluent. *E. coli*'s rate of elevation above its criteria had a range of 13% to 44%.

Dissolved iron and dissolved manganese each had elevated concentrations at only one site: Hunters Creek and Willow Creek, respectively, while total dissolved solids (TDS) and SC were not elevated in any of the surrounding water bodies.

10.1.3 Live Oak Study Area

Table 11 summarizes water quality results for key constituents collected from the Live Oak study area.

Of these key constituents, no exceedances were reported for boron, total fluoride, sulfate, dissolved iron, dissolved manganese, bromodichloromethane, or dibromochloromethane in the Live Oak study area. Only six constituents had elevated concentrations in the Live Oak POTW effluent: total arsenic, dissolved arsenic, nitrate as nitrogen, sodium, TDS, and SC. The rate of exceedance for arsenic, nitrate as nitrogen, and sodium was 100%. The rate of exceedance for TDS was 77%. Specific Conductance's rate of exceedance was only 3% and occurred sporadically.

Exceedances for all six constituents and a number of others occurred both upstream and downstream of the effluent. Sodium criteria were exceeded in 18—100% of the samples collected. Elevated concentrations of both total and dissolved arsenic were found throughout the surrounding water bodies. Dissolved arsenic was the only dissolved form (arsenic, aluminum, iron, and manganese) that was elevated above its criteria in the surrounding water bodies. The rate of elevation above its criteria for dissolved arsenic was 9—100% with no exceedances found in the furthest downstream site (Sutter Bypass).

Criteria for total aluminum, total iron, and total manganese were frequently exceeded in the surrounding water bodies, though not in the effluent. The rate of exceedance for these three constituents in the upstream and downstream sites was 20—100%. Every upstream and downstream site except for Lateral Drain #2, downstream of effluent reported with a maximum total aluminum and iron concentrations of >1000 µg/L. Every upstream and downstream site except for Lateral Drain #2, upstream of effluent reported with a maximum total manganese concentration of >100 µg/L. Highest concentrations of total aluminum, iron, and manganese ranged up to 3760 µg/L at Lateral Drain #2 upstream, 4700 µg/L at Lateral Drain #2 upstream, and 623 µg/L at Wadsworth Canal downstream, respectively (Table 6).

Nitrate as nitrogen, TDS, and SC reported elevated levels at Lateral Drain #2, just downstream of the effluent. Exceedances were not seen in any of the two further downstream sites within the study area.

There was only one sample that had elevated levels of chloroform: Lateral Drain #2, upstream of effluent. *E. coli* was elevated above its criterion in only one site: Wadsworth Canal, downstream of effluent. Only 20% (3 of 15) of the *E. coli* samples collected at Wadsworth Canal reported elevated concentrations.

10.1.4 Biggs Study Area

Table 12 summarizes water quality results for key constituents collected from the Biggs study area.

Of these key constituents, no exceedances were reported for total arsenic, dissolved arsenic, dissolved iron, nitrate as nitrogen, boron, total fluoride, suflate, bromochloromethane, and dibromochloromethane in the Biggs study area. Only seven constituents had elevated concentrations in the Biggs POTW effluent: sodium, ammonia as nitrogen, total iron, *E. coli*, TDS, SC and chloroform. The rate of exceedance for sodium and was 100%. The rate of elevation above its criteria for ammonia as nitrogen was 100% as well. The remaining constituents varied. Of the ten total iron samples collected in the effluent, two exceeded criteria (20%), while 4 of 16 *E. coli* samples reported elevated concentrations (25%). Exceedances for TDS and SC occurred in 3 of 13 samples (23%) and 1 of 29 samples (3%), respectively. Chloroform had elevated concentrations in 1 of 10 samples.

Of these seven constituents, all but TDS and SC reported exceedances upstream and/or downstream of the influence of the effluent discharge. Sodium and *E. coli* exceeded criteria in approximately 25% of samples at each site except Butte Creek at Nelson Road. Ammonia as nitrogen and chloroform were only detected above criteria at the first site downstream of the effluent discharge—at 58% and 10% frequency, respectively. The single elevated downstream chloroform concentration corresponded to the single spike in the effluent.

Elevated levels of total iron were found at near 100% frequency at every site except Butte Creek, upstream near Nelson Road. Criteria for total aluminum was frequently exceeded in the surrounding water bodies, though not in the effluent and Butte Slough, downstream of effluent with an exceedance rate of 22—100%. Total manganese was frequently exceeded at Lateral K and Main Drainage Canal. Every upstream and downstream site except for Butte Creek, upstream near Nelson Road reported with a maximum total aluminum and iron concentrations of >1000 µg/L. Every upstream and downstream site except for Butte Creek, upstream near Nelson Road reported with a maximum total manganese concentration of >100 µg/L. Highest concentrations of total aluminum, iron, and manganese ranged up to 2700 µg/L at Main Drainage Canal downstream, 3500 µg/L at Cherokee Canal upstream, and 430 µg/L at Butte Slough downstream, respectively (Table 7).

Elevated levels of ammonia as nitrogen were heavily concentrated in the effluent. The elevation rate dropped from 100% in the effluent to 58% in the first downstream site and then dissipates to only one exceedance sample in Butte Slough, the next downstream site. Biggs does not utilize nitrification technologies like the other three POTWs, therefore elevated levels of ammonia as nitrogen instead of nitrate as nitrogen was observed.

10.1.5 Exceedance General Comparison

Sodium was the only constituent that reported concentrations above the criteria both in the background sites (upstream and downstream of the effluent) and in the effluent itself at all four POTWs.

Total aluminum, total iron, and total manganese reported elevated concentrations at all sites upstream and downstream of the influence from the effluent, but not in the effluent itself (except for two of ten samples at Biggs with elevated total iron). Aluminum, iron, and manganese have correlate to historical background concentrations of metals in the surface waters of the Sacramento River Basin. The Sacramento River Watershed Sanitary Survey 2010 Update evaluation found high levels of aluminum, iron, and manganese that exceeded MCLs in the Sacramento River based on data collected by the intakes and/or various monitoring programs. A literature review of the Colusa Basin Drain water quality indicated that levels of iron and manganese often exceeded recommended limits for municipal usage from 1968 to 1971 (Turek, 1990).

In contrast, the dissolved form of aluminum was never elevated above its criteria and dissolved iron was only detected above the criteria once (Hunters Creek). Dissolved manganese was elevated above its criteria infrequently and at much lower overall concentrations at random site throughout the study area. Predominately, total form of aluminum and iron was historically observed in the Sacramento River (Alpers, Antweiler, Taylor, Dileanis, and Domagalski, 2000).

In addition to sodium, effluent of all four POTWs was consistently elevated in TDS, SC, and nitrate as nitrogen except for Biggs which was elevated in ammonia as nitrogen due to its operations. TDS, SC, nitrate as nitrogen, and ammonia as nitrogen commonly dissipated to below criteria concentrations as the water moved downstream, typically by the first downstream site.

Selected areas of the basin had elevated concentrations of total and dissolved arsenic such as Colusa and Live Oak. Both study areas had elevated levels of both the total and dissolved forms in the surrounding water bodies as well as the effluent. Elevated levels of arsenic (in both effluent and surrounding water bodies) appear to be linked to elevated levels in local groundwater. USGS' Groundwater Ambient Monitoring and Assessment (GAMA) Program found high levels of arsenic in the middle Sacramento Valley study area's groundwater (Bennet, Fram, and Belitz, 2011).

Trihalomethanes (THMs) were only consistently detected in the Willows effluent. Willow's effluent consistently reported elevated levels of chloroform, bromodichloromethane, and dibromochloromethane. The concentrations were not detected at any other site except for one chloroform sample collected upstream of the Live Oak, and a single chloroform sample in both the Biggs effluent and first downstream site.

Table 9 Summary of Key Constituent Exceedances: Colusa Study Area, April 2012—September 2013

Parameter	Criteria	Upstream					Effluent	Downstream		
		520COL006	520COL005	520COL107	520COL106	520COL003		520COL105	520COL102	520COL101
		Colusa Basin Drain, at Hwy 20	Powell Slough at Hwy 20	New Ditch, upstream of effluent	Unnamed Tributary, Upstream of effluent	Powell Slough, upstream of effluent	Colusa Effluent	Unnamed Tributary, Downstream of effluent	Powell Slough, downstream of effluent	Colusa Basin Drain, at Abel Road
Aluminum - Total	200 µg/L	**10 (10)**	**9 (10)**	**9 (9)**	**10 (10)**	**10 (10)**	0 (10)	**8 (10)**	**10 (10)**	**10(10)**
Aluminum - Dissolved	200 µg/L	0 (5)	0 (5)	0 (4)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Arsenic - Total	10 µg/L	0 (12)	0 (12)	**5 (10)**	**7 (11)**	**3 (12)**	0 (12)	**3 (12)**	**2 (12)**	0 (12)
Arsenic - Dissolved	10 µg/L	0 (5)	**1 (6)**	**4 (5)**	**4 (5)**	**2 (6)**	0 (6)	0 (6)	0 (7)	0 (6)
Iron - Total	300 µg/L	**10 (10)**	**10 (10)**	**9 (9)**	**10 (10)**	**10 (10)**	0 (10)	**9 (10)**	**10 (10)**	**10 (10)**
Iron - Dissolved	300 µg/L	0 (5)	0 (5)	0 (4)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Manganese - Total	50 µg/L	**10 (10)**	**10 (10)**	**9 (9)**	**10 (10)**	**10 (10)**	0 (10)	**9 (10)**	**10 (10)**	**10 (10)**
Manganese - Dissolved	50 µg/L	0 (5)	**2 (5)**	**1 (4)**	**4 (5)**	**1 (5)**	0 (5)	**2 (5)**	**1 (5)**	0 (5)
Nitrate as Nitrogen	10 mg/L	0 (17)	0 (17)	0 (15)	0 (14)	0 (17)	**17 (17)**	**10(17)**	0 (17)	0 (17)
Sodium	20 mg/L	**18 (18)**	**18 (18)**	**15 (15)**	**16 (16)**	**18 (18)**	**18 (18)**	**18 (18)**	**18 (18)**	**18 (18)**
TDS	500 mg/L	**1 (12)**	**6 (12)**	**9 (9)**	**9 (10)**	**5 (12)**	**12 (12)**	**12 (12)**	**7 (12)**	**1 (12)**
Specific Conductance	900 µS/cm	**1 (29)**	**9 (29)**	**20 (23)**	**17 (30)**	**9 (33)**	**17 (28)**	**20 (32)**	**16 (33)**	**2 (30)**
Boron	1000 µg/L	0 (16)	0 (17)	**5 (15)**	0 (16)	0 (17)	0 (18)	0 (17)	0 (17)	0 (18)
Fluoride - Total	2 mg/L	0 (9)	0 (9)	0 (7)	0 (8)	0 (9)	0 (9)	9 (9)	**1 (9)**	0 (9)
Sulfate	250 mg/L	0 (12)	**2 (12)**	**7 (9)**	**2 (10)**	**4 (12)**	0 (12)	**1 (12)**	**4 (12)**	0 (12)
Ammonia as Nitrogen	1.5 mg/L						0 (1)			
Chloroform	1.8 µg/L	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)
Bromodichloromethane	0.56 µg/L	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)
Dibromochloromethane	0.41 µg/L	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)
E. coli	235 MPN / 100 mL	**4 (16)**	0 (15)	**1 (12)**	**3 (14)**	**1 (16)**	0 (16)	**1 (15)**	**2 (16)**	**4 (16)**

NOTE: Results are read as number of samples with exceedances (total number of samples)

Table 10 Summary of Key Constituent Exceedances: Willows, April 2012—September 2013

Parameter	Criteria	Upstream			Effluent	Downstream			Comparison
		520GEL005	520GEL001	520GEL002		520GEL004	520GEL003	520COL109	520COL108
		Ag Drain C, 1500 ft upstream	Willow Creek at Road 61	Colusa Basin Drain at Road 61	Willows Effluent	Ag Drain C, 100 ft downstream	Ag Drain C at Road 60	Logan Creek, downstream of effluent	Hunters Creek, downstream of effluent*
Aluminum - Total	200 µg/L	**10 (10)**	**10 (10)**	**10 (10)**	0 (10)	**10 (10)**	**10 (10)**	**10 (10)**	**10 (10)**
Aluminum - Dissolved	200 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Arsenic - Total	10 µg/L	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)
Arsenic - Dissolved	10 µg/L	0 (6)	0 (6)	0 (6)	0 (6)	0 (6)	0 (6)	0 (6)	0(6)
Iron - Total	300 µg/L	**10 (10)**	**10 (10)**	**10 (10)**	0 (10)	**10 (10)**	**10 (10)**	0 (10)	**10 (10)**
Iron - Dissolved	300 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	**1 (5)**
Manganese - Total	50 µg/L	**10 (10)**	**10 (10)**	**10 (10)**	0 (10)	**9 (10)**	**9 (10)**	**10 (10)**	**10 (10)**
Manganese - Dissolved	50 µg/L	0 (5)	**2 (5)**	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Nitrate as Nitrogen	10 mg/L	0 (17)	0 (17)	0 (17)	**17 (17)**	0 (17)	0 (17)	0(15)	0 (15)
Sodium	20 mg/L	**18 (18)**	**8 (18)**	**14 (18)**	**18 (18)**	**18 (18)**	**18 (18)**	**18 (18)**	**16 (18)**
TDS	500 mg/L	0 (12)	0 (12)	0 (12)	**10 (13)**	0 (12)	0 (12)	0 (12)	0 (12)
Specific Conductance	900 µS/cm	0 (33)	0 (29)	0 (29)	**6 (33)**	0 (33)	0 (29)	0 (29)	0 (29)
Boron	1000 µg/L	0 (11)	0 (11)	0 (11)	0 (11)	0 (11)	0 (11)	0 (11)	0 (11)
Fluoride - Total	2 mg/L	0 (5)	0 (5)	0 (5)	0 (6)	0 (5)	0 (5)	0 (5)	0 (5)
Sulfate	250 mg/L	0 (12)	0 (12)	0 (12)	0 (13)	0 (12)	0 (12)	0 (12)	0 (12)
Ammonia as Nitrogen	1.5 mg/L				0 (1)				
Chloroform	1.8 µg/L	0 (4)	0 (4)	0 (4)	**8 (9)**	0 (9)	0 (4)	0 (4)	0 (4)
Bromodichloromethane	0.56 µg/L	0 (4)	0 (4)	0 (4)	**8 (9)**	0 (9)	0 (4)	0 (4)	0 (4)
Dibromochloromethane	0.41 µg/L	0 (4)	0 (4)	0 (4)	**8 (9)**	0(9)	0 (4)	0 (4)	0 (4)
E. coli	235 MPN / 100 mL	**4 (16)**	**2 (16)**	**4 (16)**	0 (16)	**7 (16)**	**7 (16)**	0 (16)	**3 (16)**

NOTE:
Results are read as number of samples with exceedances (total number of samples)
Hunters Creek site receives no effluent and is only a comparison site.

Table 11 Summary of Key Constituent Exceedances: Live Oak, April 2012—September 2013

Parameter	Criteria	Upstream		Effluent	Downstream		
		520SUT008	520SUT006		520SUT007	520SUT005	520SUT004
		Lateral Drain #2, upstream	Sutter Bypass, upstream of effluent	Live Oak Effluent	Lateral Drain #2, downstream	Wadsworth Canal, downstream of effluent	Sutter Bypass, downstream of effluent
Aluminum - Total	200 µg/L	**7 (10)**	**10 (10)**	0 (10)	0 (10)	**10 (10)**	**10 (10)**
Aluminum - Dissolved	200 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Arsenic - Total	10 µg/L	**12 (18)**	0 (17)	**17 (18)**	**15 (18)**	**1 (17)**	**1 (18)**
Arsenic - Dissolved	10 µg/L	**9 (12)**	0 (11)	**12 (12)**	**12 (12)**	**1 (11)**	0 (12)
Iron - Total	300 µg/L	**4 (10)**	**10 (10)**	0 (10)	0 (10)	**10 (10)**	**10 (10)**
Iron - Dissolved	300 µg/L	0 (4)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Manganese - Total	50 µg/L	**6 (10)**	**10 (10)**	0 (10)	**2 (10)**	**9 (10)**	**10 (10)**
Manganese - Dissolved	50 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Nitrate as Nitrogen	10 mg/L	**12 (18)**	0 (16)	**18 (18)**	**16 (18)**	0 (17)	0 (17)
Sodium	20 mg/L	**18 (18)**	**3 (17)**	**18 (18)**	**18 (18)**	**5 (17)**	**4 (18)**
TDS	500 mg/L	**10 (12)**	0 (11)	**10 (13)**	**7 (12)**	0 (11)	0 (12)
Specific Conductance	900 µS/cm	**1 (28)**	0 (29)	**1 (33)**	**1 (32)**	0 (26)	0 (29)
Boron	1000 µg/L	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)
Fluoride - Total	2 mg/L	0 (5)	0 (5)	0 (6)	0 (5)	0 (5)	0 (5)
Sulfate	250 mg/L	0 (12)	0 (11)	0 (13)	0 (12)	0 (11)	0 (12)
Ammonia as Nitrogen	1.5 mg/L			0 (1)			
Chloroform	1.8 µg/L	**1 (5)**	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Bromodichloromethane	0.56 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Dibromochloromethane	0.41 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
E. coli	235 MPN / 100 mL	0 (15)	0 (16)	0 (15)	0 (14)	**3 (15)**	0 (16)

NOTE: Results are read as number of samples with exceedances (total number of samples)

Table 12 Summary of Key Constituent Exceedances: Biggs, April 2012—September 2013

Parameter	Criteria	Upstream			Effluent	Downstream		
		520BUT902	520BUT004	520BUT002		520BUT003	520BUT001	520COL104
		Butte Creek, upstream near Nelson Road	Lateral K, 100 feet upstream	Cherokee Canal, upstream of effluent discharge	Biggs Effluent	Lateral K, 100 feet downstream	C Main Drain, downstream of effluent discharge	Butte Slough, downstream of effluent discharge at Farmlan Road
Aluminum - Total	200 µg/L	**2 (9)**	**10 (10)**	**6 (10)**	0 (10)	**9 (10)**	**10 (10)**	0 (9)
Aluminum - Dissolved	200 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Arsenic - Total	10 µg/L	0 (17)	0 (18)	0 (18)	0 (18)	0 (18)	0 (18)	0 (17)
Arsenic - Dissolved	10 µg/L	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)
Iron - Total	300 µg/L	0 (9)	**10 (10)**	**10 (10)**	**2 (10)**	**9 (10)**	**10 (10)**	**9 (9)**
Iron - Dissolved	300 µg/L	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
Manganese - Total	50 µg/L	0 (9)	**9 (10)**	**4 (10)**	0 (10)	**8 (10)**	**9 (10)**	**0 (9)**
Manganese - Dissolved	50 µg/L	0 (5)	**3 (5)**	0 (5)	0 (5)	**2 (5)**	0 (5)	**1 (5)**
Nitrate as Nitrogen	10 mg/L	0 (11)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)
Sodium	20 mg/L	0 (17)	**4 (18)**	0 (18)	**18 (18)**	**7 (18)**	**3 (18)**	**3 (17)**
TDS	500 mg/L	0 (12)	0 (12)	0 (12)	**3 (13)**	0 (12)	0 (12)	0 (12)
Specific Conductance	900 µS/cm	0 (28)	0 (29)	0 (29)	**1 (29)**	0 (29)	0 (29)	0(28)
Boron	1000 µg/L	0 (11)	0 (12)	0 (12)	0 (12)	0 (12)	0 (12)	0 (11)
Fluoride - Total	2 mg/L	0 (5)	0 (5)	0 (5)	0 (6)	0 (5)	0 (5)	0 (5)
Sulfate	250 mg/L	0 (12)	0 (12)	0 (12)	0 (13)	0 (12)	0 (12)	0 (12)
Ammonia as Nitrogen	1.5 mg/L	0 (12)	0 (12)	**1 (12)**	**13 (13)**	**7 (12)**	0 (12)	**1 (12)**
Chloroform	1.8 µg/L	0 (4)	0 (5)	0 (5)	**1 (10)**	**1 (10)**	0 (5)	0 (4)
Bromodichloromethane	0.56 µg/L	0 (4)	0 (5)	0 (5)	0 (10)	0 (10)	0 (5)	0 (4)
Dibromochloromethane	0.41 µg/L	0 (4)	0 (5)	0 (5)	0 (10)	0 (10)	0 (5)	0 (4)
E. coli	235 MPN / 100 mL	0 (16)	**4 (16)**	0 (16)	**4 (16)**	**5 (16)**	**6 (16)**	**1 (16)**

NOTE: Results are read as number of samples with exceedances (total number of samples)

10.2 Spatial and Temporal Trends

The overall study area has been hydrologically modified with flow highly managed to support agricultural operations. The study area on the west side of the Sacramento River Basin included the Colusa Basin watershed and the east side included Lower Butte Creek watershed and Sutter Bypass. These water bodies either represented background condition or received effluent from cities of Colusa, Willows, Live Oak, or Biggs.

In the following sections, data is analyzed both spatially and temporally. Each study area within each side of the basin in addition to the overall east and west sides of the basin are evaluated and compared.

For the sets of figures presented to discuss spatial and temporal analysis for each side of the basin, the first figure shows a box and whiskers representation of the minimum, maximum, median, 1st, and 3rd quartiles for the parameters for each site, moving downstream (background, effluent, receiving water) while the second figure shows actual data points collected during the sampling period as compared to time and season.

Specific conductance, nitrate as nitrogen, arsenic (dissolved and total), trihalomethanes, ammonia as nitrogen, and *E. coli* are the focus of this discussion. These constituents were chosen because they were either continuously detected, exceeded the evaluation criteria in the effluent or in one or more upstream/downstream sampling sites, and/or showed distinct patterns.

10.2.1 West Side Sacramento River Basin—Colusa and Willows Study Area

<u>Specific Conductance (SC)</u>

Specific conductance (SC) is evaluated against the Secondary MCL at 900 µmhos/cm, which is the recommended level for continuous drinking water use.

Specific conductance (SC) in both the Colusa and Willows study areas followed a pattern of gradual increase in concentrations from upstream sites leading to effluent then gradual decrease downstream from the effluent (Figure 9). Sites in the Colusa study area reached higher concentrations of SC than sites in Willows study area. Concentration for the Willows study area peaked at Willows effluent site at 1,682 µmhos/cm, while Colusa study area peaked at New Ditch site at 3,465 µmhos/cm. Unlike the Colusa study area, Willow's effluent had the highest SC concentrations in its study area. Colusa study area's highest SC concentration is double Willow's. New Ditch also had the greatest variation between 1st and 3rd quartile in SC concentrations. The maximum SC recorded in Colusa's effluent was less than the maximum at the other study area sites. The Colusa effluent does not appear to influence concentrations of SC in the study area.

Colusa study area had more variable SC concentrations throughout the sampling period compared to the Willows study area except for the consistency of the effluent and Colusa Basin

Drain (Figure 10). Highest SC peaked in February 2013 at New Ditch. The majority of the samples exceeded the Secondary MCL criteria of 900 µmhos/cm. All of the sites had exceedance in one or more samples throughout the sampling period.

The SC spikes in the Colusa study area did not correlate with any significant high flow or rainfall patterns. Concentrations spikes of specific conductance seem to occur when there was low flow and no rainfall events. All of the sites except the effluent peaked on February 28, 2013. The effluent peak correlated to no rainfall and a very low flow of 183 cfs.

The Willows study area (Figure 11) had a more consistent pattern of conductance concentrations. There is a clear spike on April 9, 2013 at three sites (Willows effluent and just upstream and downstream of the effluent in Ag Drain C). There is a large decrease in SC concentrations in December 2012 for all sites.

Elevated levels of specific conductance in Willows could possibly be related to rainfall patterns. Although concentrations typically did not exceed the criteria of 900 µmhos/cm, there were elevated concentrations at most sites in April 2012 and 2013 and October/November 2012. Rainfall occurred a few days right before these elevated specific conductance concentrations.

Nitrate as Nitrogen

Nitrate as nitrogen is evaluated against the Primary MCL at 10 mg/L.

Both Colusa and Willows study area (Figure 12) had the highest concentrations of nitrate as nitrogen at their effluent sites. Willows peaked at a concentration of 44.8 mg/L and Colusa peaked at 31 mg/L. Both Colusa and Willows POTWs use nitrification technology to convert ammonia as nitrogen to nitrate as nitrogen in wastewater. The elevated effluent concentration caused a slight increase just downstream of Willows and a more pronounced effect just downstream of Colusa. The effluent effect became negligible further downstream. Greatest variation between 1st and 3rd quartile in nitrate as nitrogen concentrations was seen at Unnamed Tributary downstream of the Colusa effluent. Only Willows effluent, Colusa effluent, and Unnamed Tributary downstream of Colusa’s effluent exceeded the Primary MCL criteria of 10 mg/L.

The Colusa study area (Figure 13) had several temporal variations in reported nitrate as nitrogen concentrations. The Colusa effluent and Unnamed Tributary just downstream exceeded the Primary MCL criteria on several occasions but the downstream pattern of exceedance did not always match. The concentration patterns of several sites stayed low. Colusa effluent had a pattern of increase in one month then decrease in the next month then increase in the following month. Unnamed Tributary downstream had a similar pattern of concentration change as Colusa effluent but the fluctuations between peaks and the lows were greater and did not correlate consistently with effluent concentrations.

The very large nitrate as nitrogen fluctuations in the Colusa study area occurred during the months of October to January. During these months, there were storm events and high flows.

Nitrate as nitrogen concentrations seem to increase several days after each storm event during the winter months.

Similar to specific conductance, Willows study area's nitrate as nitrogen concentrations (Figure 14) had a more consistent pattern compared to Colusa in all sites except for the effluent. Only Willows effluent had exceedance at all times throughout the sampling period with the highest peak on October 25, 2012 at 44.8 mg/L, followed by smaller peaks on March 27, 2013 and June 18, 2013. For the other sites, nitrate as nitrogen concentrations stayed relatively similar with small peaks during September to October months and in late February to March months.

Willow's highest nitrate as nitrogen peak concentration occurred a few days after a storm event that took place in October 2012. Rainfall occurred a few days before the other two smaller peaks of nitrate as nitrogen concentration observed in March and June 2013 as well. Flow stayed fairly low during each of the nitrate peak concentrations.

Arsenic

Total arsenic is evaluated against the Primary MCL at 10 µg/L. As mentioned in Section 10.1, dissolved form of arsenic does not have an evaluation criterion so it is evaluated against the Primary MCL of total arsenic. Only the Colusa study area on the west side of the Sacramento River basin had arsenic concentrations that were above the evaluation criteria.

The Colusa study area had higher total arsenic concentrations at two sites upstream of the effluent discharge than downstream sites (Figure 15). The highest total arsenic concentration reached was at 41 µg/L at Unnamed Tributary upstream of the effluent discharge. Greatest variation between the 1st and 3rd quartile was also observed at Unnamed Tributary upstream. All of the sites had at least one arsenic sample that exceeded 10 µg/L except for Colusa Basin Drain at Hwy 20, Colusa effluent, and Colusa Basin Drain at Abel Road.

Most of the total arsenic samples stayed below 10 µg/L (Figure 17). Concentrations for most sites stayed constant. Highest concentration of total arsenic peaked on September 25, 2012 and June 18, 2013 at Unnamed Tributary upstream at 41 µg/L and 30 µg/L, respectively. For the months of October 2012 through April 2013, concentrations at all sites except for Unnamed Tributary upstream did not have fluctuations. All of the total arsenic peaks occurred during low flow and no rainfall. There is a large decrease in total arsenic concentrations for all of the sites on May 29, 2012. As measured at rain and flow stations on the west side of the river basin, there was no rainfall on May 29, 2012 but the flow did increased by a small amount compared to early April 2012.

Dissolved arsenic was collected less frequently than total arsenic and only covers the period from April 24, 2013 to September 24, 2013. Dissolved arsenic concentrations at the Colusa study area (Figure 16) followed a very similar pattern to total arsenic in Figure 15 though at overall lower concentrations. The highest dissolved arsenic concentration reached was at 25 µg/L at Unnamed Tributary upstream. Greatest variation between the 1st and 3rd quartile was also observed at Unnamed Tributary upstream. Effluent site and sites downstream from the effluent showed no exceedanes of the Primary MCL criteria of 10 µg/L.

Colusa study area's dissolved arsenic temporal concentrations (Figure 18) for most sites are consistent with no large fluctuation with the exception of New Ditch and Unnamed Tributary upstream. Peak concentrations occurred at all sites in June 2013 which is during the irrigation period. Similar to total arsenic concentration patterns, dissolved arsenic concentrations peaked while there was low flow and no rainfall.

When comparing the peak of total and dissolved arsenic at Unnamed Tributary, upstream of effluent, total arsenic exceeded the Primary MCL more frequently than dissolved arsenic. The peak total arsenic concentration of 41 µg/L is almost double the amount of dissolved arsenic concentration of 25 µg/L.

Both total and dissolved arsenic concentration spikes did not correlate to turbidity concentration spikes observed in Colusa (Figure 19). Arsenic concentration patterns did not match up to turbidity concentration patterns except for the Colusa effluent. Peak arsenic concentrations were not observed and turbidity remained below 5 NTU for the Colusa effluent site throughout the sampling period. New Ditch had very high concentration spikes in turbidity due to very low water levels and flow.

Trihalomethanes

Trihalomethanes (THMs) are evaluated against the California Toxics Rule (CTR) at 4.3 µg/L for bromoform, 0.56 µg/L for bromodichloromethane, and 0.41 µg/L for dibromochloromethane with the exception of chloroform. Chloroform is evaluated against the Cal/EPA Cancer Potency Factor as a drinking water level (assumes 70kg body weight and 2 liters per day drinking water consumption at 1.8 µg/L).

Only the Willows study area had elevated levels of THMs with detectable concentrations occurring in each of the nine effluent samples and the majority of concentrations exceeding criteria, except for the bromoform criteria which was never exceeded. In the effluent, chloroform ranged from 4.6 to 50 µg/L, bromodichloromethane from 1.3 to 17 µg/L; and dibromochloromethane from 0.2 to 2.9 µg/L (Figure 20). For the surrounding water bodies, trihalomethane concentrations were below evaluation criteria and reporting limit throughout the sampling period.

Trihalomethane concentrations peaked in May 2012, August 2012, September 2012, and June 2013 at the effluent (Figure 21). Changes in concentrations seem to depend on seasonal changes. The spring and summer months had higher concentration of THMs than the winter months. As measured at the flow stations in the west side of the river basin, flow was relatively low during all peak THMs concentrations.

E. coli

E. coli is evaluated against the USEPA Recreational Guideline for Designated Beach Area at 235MPN/100mL (USEPA, 1986). This numeric water quality criterion is strictly used as a tool for evaluation to put values in to context in terms of spatial and temporal trends. The purpose of this study was not designed to evaluate the impacts of pathogens on recreational water. Since the completion of the 18-month monitoring design, new pathogen regulations were established based on most current scientific information by the USEPA (USEPA, 2012).

Concentrations at some sites fell below the lower reporting limit (<1 MPN/100mL) and above the upper reporting limit (>2419.6 MPN/100mL). To create these figures, values had to be assigned for each of these occurrences. For the purposes of making these figures, samples below or above the reporting limit were calculated with the respective reporting limit.

Generally, *E. coli* in Colusa and Willows study area (Figure 22) followed a pattern of gradual decrease from upstream sites leading to effluent then gradual increase downstream from the effluent. *E.* coli was not detected at any time in either the Colusa or Willows effluent. Both effluent sites had a concentration level of <1 MPN/100mL during the entire sampling period. Almost all other sites had one sample that exceeded 235 MPN/100mL but concentrations at these sites varied with at least 75% (3rd quartile) of each site below 235 MPN/100mL except at Ag Drain C just below the Willows effluent of the water bodies. Powell Slough seemed to consistently have the lowest overall concentration aside from the effluent while Colusa Basin Drain had the highest overall concentrations except for Ag Drain C.

Concentrations above 235 MPN/100mL occurred on a limited basis at different sites during different times of the year. In the Colusa study area (Figure 23), peak concentrations were observed in August 2012 at Colusa Basin Drain at HWY 20. A small spike occurred in the beginning of January 2013 at Colusa Basin Drain at HWY 20 and Colusa Basin Drain at Abel Road. More peaks occurred in the months of March and April 2013—the beginning of irrigation period and wetland drainage; the highest concentration reached 866 MPN/100mL at Unnamed Tributary, upstream of effluent. At the end of the irrigation period in September 2013 , a spike is seen with a concentration of >2419.6 MPN/100mL at New Ditch, upstream of effluent, Unnamed Tributary, upstream of effluent, and Powell Slough, downstream of effluent.

Peaks observed for *E. coli* did not seem to correlate with flow or rainfall patterns with the exception of the peaks seen in September 2013. As measured on the west side of the river basin, flow was elevated in late August 2013 and a rainfall event occurred a few days right before the high spike in September 2013. The elevated *E. coli* was reported in the upstream sites. *E. coli* concentrations return to below 200 MPN/100mL for downstream sites.

In the Willows study area (Figure 24), spiked concentrations occurred randomly throughout the sampling period. Ag Drain C, 100ft downstream of the effluent had the most reported concentrations >235 MPN/100mL out of all sites throughout the year. Highest concentrations peaked in October 2012 and May 2013 at >2419.6 MPN/200mL when there was no rainfall and low flow. There were peaks that occurred in January 2013 at Hunters and Willow Creek. The

January peaks may be related to a rainfall event that occurred a few days before elevated concentrations of *E. coli*.

Aside from the *E. coli* concentration spikes noted, most of the individual sites had concentrations that were below 235 MPN/100mL throughout the sampling period. Both effluent sites on the west side of the basin had concentration levels of <1 MPN/100mL during the entire sampling period.

10.2.2 East Side Sacramento River Basin—Live Oak and Biggs Study Area

<u>Specific Conductance (SC)</u>

Specific conductance (SC) is evaluated against the Secondary MCL at 900 µmhos/cm, which is the recommended level for continuous drinking water use.

Both, Live Oak and Biggs study area (Figure 25) followed a pattern of gradual decrease of SC concentrations downstream from the effluent. Samples collected at the Biggs study area generally had lower concentrations than the Live Oak study area. There was no exceedance of the Secondary MCL criteria (900 µmhos/cm) observed in the Biggs study area. The Live Oak study area had 3 sites that exceeded the criteria: Lateral Drain #2 upstream, Live Oak effluent, and Lateral Drain #2 downstream. Concentrations for the Biggs study area peaked at Biggs effluent site at 900 µmhos/cm, while Live Oak study area peaked at Lateral Drain #2 upstream site at 1,148 µmhos/cm. The effluent may impact downstream sites for both study areas since the effluent concentrations are generally higher than the concentrations observed downstream, however the differences in concentration are minimal and inconsistent. Lateral Drain #2's SC concentrations were similar to SC concentrations observed in the effluent at Live Oak. The source of Lateral Drain #2 is mainly backflow of effluent water and some storm water during the winter season.

The Live Oak study area (Figure 26) had more consistent conductance concentration patterns than Biggs (Figure 27). For the Live Oak study area, there is a distinction between the sites close to the effluent (Lateral Drain #2 upstream, effluent, Lateral Drain #2 downstream) and sites that are further downstream from the effluent (Sutter Bypass upstream, Wadsworth Canal, and Sutter Bypass downstream). Highest SC peaked in June 2012 at Lateral Drain #2, upstream of effluent, which exceeded the Secondary MCL criteria. Concentrations within each site stayed consistent except for some peaks that occurred, although most of these peaks did not exceed the criteria.

Most elevated concentrations in the Live Oak study area appear to correlate to storm events except for the large peak that exceeded the criteria during June 2012 in the effluent and Lateral Drain #2. No rainfall or high flow event occurred during June 2012.

The Biggs study area (Figure 27) had more variable SC concentrations throughout the sampling period compared to Live Oak. There was no clear distinction between the sites except for the effluent. Biggs effluent had a much higher level of SC compared to the rest of the sites. Specific conductance peaked at most of the sites in April 2012, October 2012, December 2012, and January to March 2013, although the criteria were never exceeded.

For the peaks observed in April, October, and December 2012, there was no rainfall or high flow event that occurred. These patterns of SC concentration are similar to the west side of the river basin. Agricultural production on both the east and west sides of the river basin also is dominated by rice. Flooding of the rice fields typically take place in March—April and draining occurs in the summer and flooding occurs again in September for duck clubs. But for the January to March 2013 period, there were multiple rainfall events that could have influenced the SC peaks observed.

Nitrate as Nitrogen

Nitrate as nitrogen is evaluated against the Primary MCL of 10 mg/L. Nitrate as nitrogen is only discussed for Live Oak study area for the east side of the Sacramento River basin because the Biggs study area did not have elevated levels of nitrate as nitrogen. The Biggs POTW does not use nitrification technology so elevated levels of ammonia as nitrogen was observed and is discussed separately. Maximum reported nitrate as nitrogen concentrations in the Biggs study area were all below 1 mg/L.

Similar to SC concentrations in the Live Oak study area (Figure 25), the sites that are near the effluent (Lateral Drain #2 upstream, Live Oak effluent, and Lateral Drain #2 downstream) have much higher concentrations of nitrate as nitrogen than the sites that are further downstream from the effluent (Sutter Bypass upstream, Wadsworth Canal, and Sutter Bypass, downstream) (Figure 28). Exceedance of the Primary MCL criteria of 10 mg/L were observed in the sites that are near the effluent. Highest peak concentration occurred at 19.6 mg/L at the Live Oak effluent site. Greatest variation between 1st and 3rd quartile in nitrate as nitrogen concentrations was observed at Lateral Drain #2, upstream of effluent. Lateral Drain #2 is highly influenced by the effluent site since Lateral Drain #2 contained backflow effluent water. The effluent effect was negligible in the Sutter Bypass and further downstream where all reported concentrations were less than 1 mg/L.

Distinct peaks of nitrate as nitrogen are seen in June/July 2012, September 2012, November/December 2012, and in April 2013 (Figure 29). A large decrease of nitrate as nitrogen concentration was observed in the beginning of the year of 2013 at Lateral Drain #2, upstream. This reflects the variation observed with the 1st and 3rd quartile in Figure 28. Fluctuations were minimal in Sutter Bypass upstream, Wadsworth Canal, and Sutter Bypass downstream throughout the sampling period.

The effluent and Lateral Drain #2 sites often exceeded the criteria. The peaks observed in June—July 2012, September—beginning of November 2013, and April—June 2013 seems to have occurred when flow was low and there were no rainfall events. When high or fluctuating flow and rainfall event occurred, concentrations of nitrate as nitrogen decreased.

Arsenic

Total arsenic is evaluated against the Primary MCL at 10 µg/L. As mentioned in Section 10.1, dissolved form of arsenic does not have an evaluation criterion so it is evaluated against the Primary MCL of total arsenic. Only the Live Oak study area on the east side of the Sacramento River basin had arsenic concentrations that were above the evaluation criteria.

Total arsenic levels for the Live Oak study area (Figure 30) seem to fluctuate largely between upstream, effluent, and downstream sites. The highest total arsenic concentration reached was at 40 µg/L at 3 sites: Lateral Drain #2 upstream, Live Oak effluent, and Lateral Drain #2 downstream. The greatest variation between 1st and 3rd quartile was observed at Lateral Drain #2, upstream of effluent. Concentrations of total arsenic decreased moving downstream from the effluent. All of the sites except for Sutter Bypass, upstream of effluent had at least one sample that exceeded the criteria of 10 µg/L. Most of the sites with total arsenic exceedances corresponded to effluent exceedances except for one sample collected at Wadsworth Canal and another sample collected at Sutter Bypass downstream.

Although many of the results did not exceed the Primary MCL criteria of 10 µg/L, there were large fluctuations of total arsenic (Figure 32) for the sites near the effluent and the Wadsworth Canal throughout the sampling period. The largest peaks of total arsenic related to the effluent are observed in the month of October 2012. Sutter bypass upstream and downstream had consistent levels of total arsenic throughout the sampling period. Lateral Drain #2 experiences a dramatic drop in total arsenic levels from January to March 2013, while the Wadsworth Canal showed an increase during the same time period.

A high rainfall event occurred a few days before the large peak observed in October 2012. Flow was quite low even though there was a high rainfall event. The dramatic drop observed in December 2012 to March 2013 is most likely influenced by the combination of high flows and multiple rainfall events.

Dissolved arsenic was collected less frequently than total arsenic and only covers the period from September 26, 2012 to September 26, 2013. Dissolved arsenic concentrations at the Live Oak study area (Figure 31) followed a very similar pattern to total arsenic in Figure 30. Dissolved arsenic levels decreased moving downstream from the effluent. Highest level of dissolved arsenic peaked at 38.7 µg/L at the effluent site. The greatest variation between 1st and 3rd quartile was observed at Lateral Drain #2, upstream of effluent. Similar to total arsenic, Sutter Bypass upstream was the only site that did not have any samples that exceeded the Primary MCL criteria of 10 µg/L for dissolved arsenic.

Seasonal fluctuations observed for Live Oak study area's dissolved arsenic (Figure 33) were less dramatic than total arsenic. Similar to total arsenic, the largest peaks of dissolved arsenic are observed in the month of October 2012. Sutter bypass upstream and downstream had consistent levels of dissolved arsenic throughout the sampling period. Lateral Drain #2 experiences the same dramatic drop in dissolved arsenic as seen for the total arsenic levels in December 2012 to March 2013.

When comparing total and dissolved arsenic concentrations in the Live Oak study area, total arsenic had higher concentrations than dissolved arsenic, however the difference was minimal. Majority of the arsenic that was found in Live Oak study area seem to be in the dissolved form.

Both total and dissolved arsenic concentration spikes did not correlate to turbidity concentration spikes observed in Live Oak (Figure 34). Arsenic concentration patterns did not match up to turbidity concentration patterns. Lateral Drain #2, upstream of effluent had very high turbidity concentrations and this is due to a lot of plant growth and fecal matter from the many fishes that was present in the water.

Ammonia as Nitrogen

Ammonia is evaluated against the Odor threshold (Amoore and Hautala) criteria at 1.5 mg/L. The Odor threshold is the most appropriate guideline based on the narrative Tastes and Odors water quality objective in the basin plan[1]. Ammonia was only evaluated for the Biggs study area. The Biggs POTW was the only POTW out of the four that did not use nitrification technology and therefore produced ammonia as nitrogen instead of nitrate as nitrogen in the effluent.

For ammonia as nitrogen (Figure 35), only the effluent and the first downstream site exceeded the Odor Threshold criteria of 1.5 mg/L. Highest concentration of ammonia peaked at 14 mg/L at the Biggs effluent site. The greatest variation between 1st and 3rd quartile was also observed at the effluent site. The elevated effluent concentration caused an increase just downstream of Biggs. The effluent effect became negligible further downstream. There were no detected concentrations of ammonia as nitrogen in the Cherokee Canal.

Lateral K upstream, Main Drainage Canal, and Butte Slough had a consistent concentration level of ammonia as nitrogen (Figure 36) that was below the Odor Threshold criteria throughout the sampling period. Biggs effluent and Lateral K downstream had the largest fluctuations of ammonia as nitrogen throughout the sampling period. As ammonia as nitrogen concentrations increased in the effluent during November 2012, April 2013, June 2013, and August 2013, concentrations decreased in the Lateral K downstream site. Large peaks of concentration occurred on September 2012, November 2012, and August 2013. Ammonia as nitrogen concentrations seem to be higher in spring/summer months and lower in winter months. During the large peaks of ammonia concentrations, flow was relatively low and rainfall did not occur.

[1]Ammonia as nitrogen does have a more stringent criteria for protecting aquatic life [USEPA National Recommended Water Quality Criteria for aquatic life (4 day average as N) at 0.49 mg/L]. Elevated ammonia concentration that is above the Odor threshold will be above the USEPA National Recommended Water Quality Criteria for aquatic life as well.

E. coli

E. coli is evaluated against the USEPA Recreational Guideline for Designated Beach Area at 235MPN/100mL (USEPA, 1986). This numeric water quality criterion is strictly used as a tool for evaluation to put values in to context in terms of spatial and temporal trends. The purpose of this study was not designed to evaluate the impacts of pathogens on recreational water. Since the completion of the 18-month monitoring design, new pathogen regulations were established based on most current scientific information by the USEPA (USEPA, 2012).

Concentrations of *E.* coli at some sites fell below the lower reporting limit (<1 MPN/100mL) and above the upper reporting limit (>2419.6 MPN/100mL). To create these figures, values had to be assigned for each of these occurrences. For the purposes of making these figures, samples below or above the reporting limit were calculated with the respective reporting limit.

Effluent concentrations for both Live Oak and Biggs generally remained below 235 MPN/100mL and did not appear to influence surrounding sites (Figure 37). Higher concentrations of *E. coli* were found both upstream and downstream of each effluent site. *E. coli* was not detected at any time in the Live Oak effluent. Concentrations for the Live Oak study area peaked at Wadsworth Canal at 1299.7 MPN/100mL, while Biggs study area peaked at >2419.6 MPN/100mL at Biggs effluent and Lateral K upstream. Greatest variation between 1st and 3rd quartile in *E.* coli was observed at Lateral K, downstream of the Biggs effluent. Almost all sites in the Biggs study area had at least one sample that exceeded 235 MPN/100mL except for Butte Creek and Cherokee Canal, upstream of effluent. Contrary to the Biggs study area, the Live Oak study area only had exceedances at one site; Wadsworth Canal.

Distinct peaks occurred in September 2012 and May 2013 at Wadsworth Canal (Figure 38). Peaks observed did not seem to correlate with any rainfall or high flow events. Flow was relatively low when these peaks occurred.

The Biggs study area (Figure 39) had two distinct peaks reaching >2419.6 MPN/100mL in October 2012 at Biggs effluent and April 2013 at Lateral K upstream. The two distinct peaks that occurred in Biggs did not correlate to any rainfall or high flow events. Once again, the flow was relatively low when these peak concentrations of *E. coli* occurred. Most of the Biggs sites did not exceed the criteria of 235 MPN/100mL throughout the sampling period, although it did have small peaks in winter months and spring/summer months. The peaks that occurred during winter months may correlate to rainfall events and spring/summer months may correlate to no rainfall and low flow. The peaks observed in the spring/summer months were higher than the winter months.

Spatial and Temporal Trends General Comparison

Specific conductance, nitrate as nitrogen, arsenic (dissolved and total), trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane), ammonia as nitrogen, and *E. coli* displayed variations in spatial and temporal trends. The correlation between peak concentrations and flow and/or rainfall events was variable. Peak concentrations appear to be more closely correlated with flow patterns than specific seasons, except for *E. coli*. Concentrations of *E. coli* were elevated during spring and early summer.

Effluent from all of the POTWs (except Biggs) had elevated nitrate as nitrogen that appeared to impact the first downstream site but dissipate further downstream. Biggs effluent had elevated ammonia. Willow's effluent was unique in that it was the only one that consistently reported THMs.

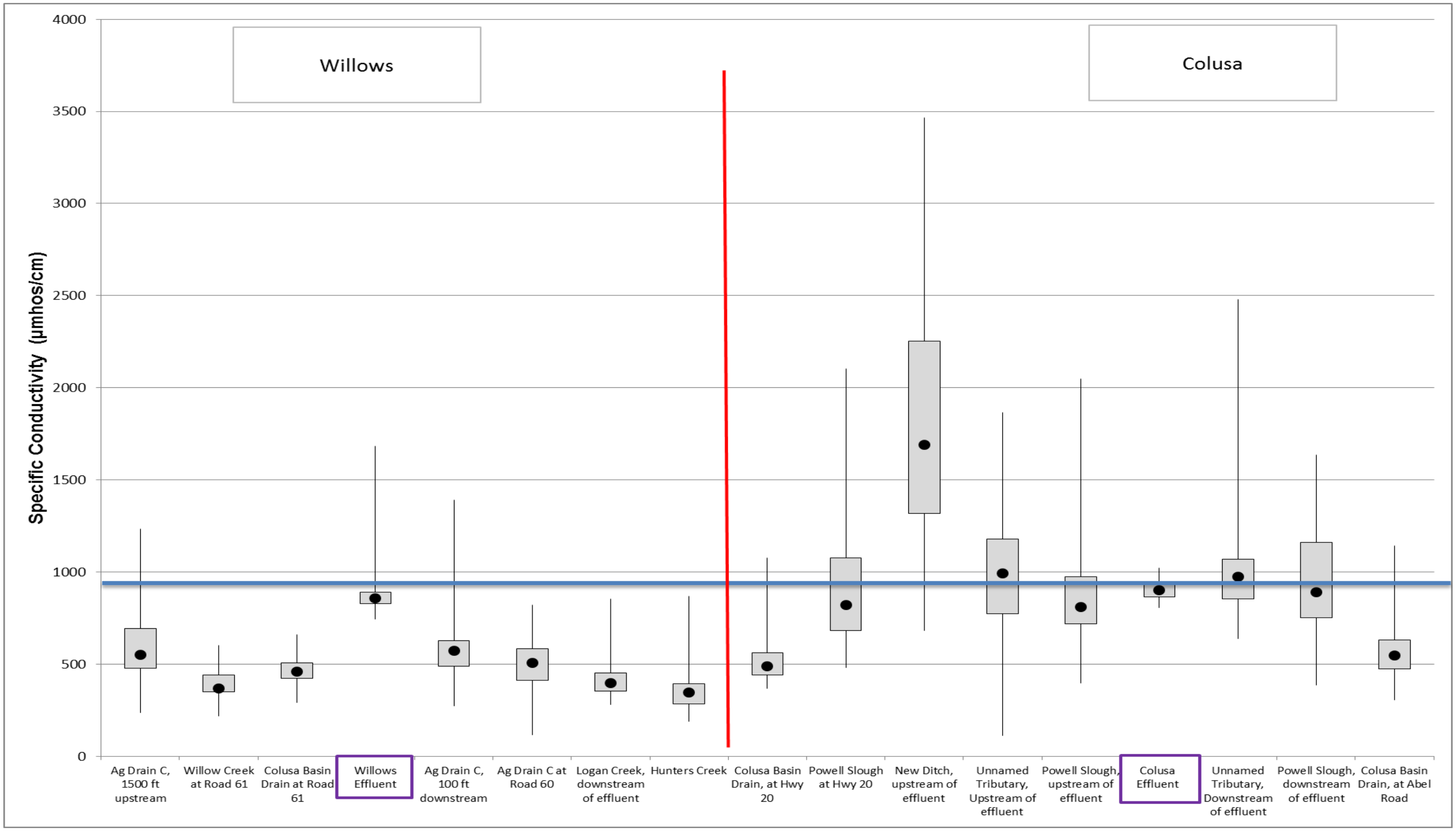
Some spatial trends were evident when comparing east (Live Oak and Biggs study area) vs. west (Colusa and Willows study area) side of the Sacramento River basin, as well as north (Willows and Biggs study area) vs. south (Colusa and Live Oak study area) side of the basin.

The east side of the basin reported background concentrations of nitrate as nitrogen, ammonia and overall lower E. coli concentrations than the west side, while the west side of the basin reported higher overall SC concentrations. The southern portion of the basin was the area that reported elevated total and dissolved arsenic.

Constituent correlations with flows and/or seasons were variable. On the east side of the river basin, peak concentrations in nitrate as nitrogen, ammonia as nitrogen, and *E. coli* correlated with low flow and no rainfall. Contrary to these hydrology patterns, SC peak concentrations correlated with low flow and no rainfall or high flow and rainfall; and arsenic peak concentrations correlated with high flow and rainfall. Ammonia as nitrogen and *E. coli* concentrations observed in spring/summer months are higher than the concentrations in winter months.

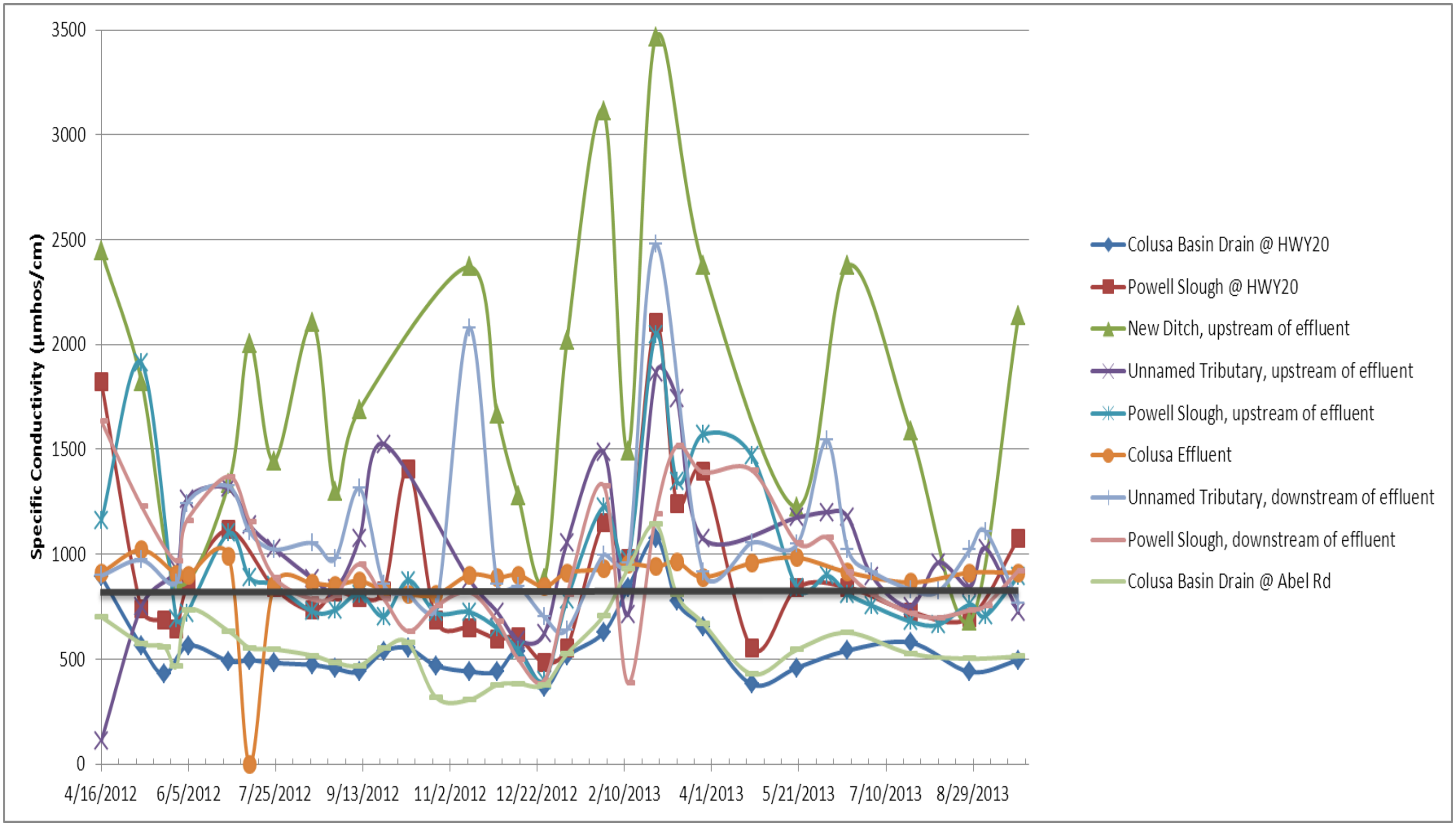
On the west side of the river basin, peak concentrations in SC, arsenic, and trihalomethanes correlated with low flow and no rainfall. Contrary to these hydrology patterns, nitrate as nitrogen peak concentrations correlated with high flow and rainfall; and *E. coli* peak concentrations were elevated when there were low flows in the water bodies. Similar to ammonia as nitrogen and *E. coli* on the east side of the river basin, trihalomethanes had higher concentrations in spring/summer months than winter months.

Figure 9 Summary Specific Conductance: West Sacramento River Basin, April 2012—September 2013



SC criteria: 900 µmhos/cm

Figure 10 Colusa Study Area: Specific Conductance, April 2012—September 2013



SC criteria: 900 µmhos/cm

Figure 11 Willows Study Area: Specific Conductance, April 2012—September 2013

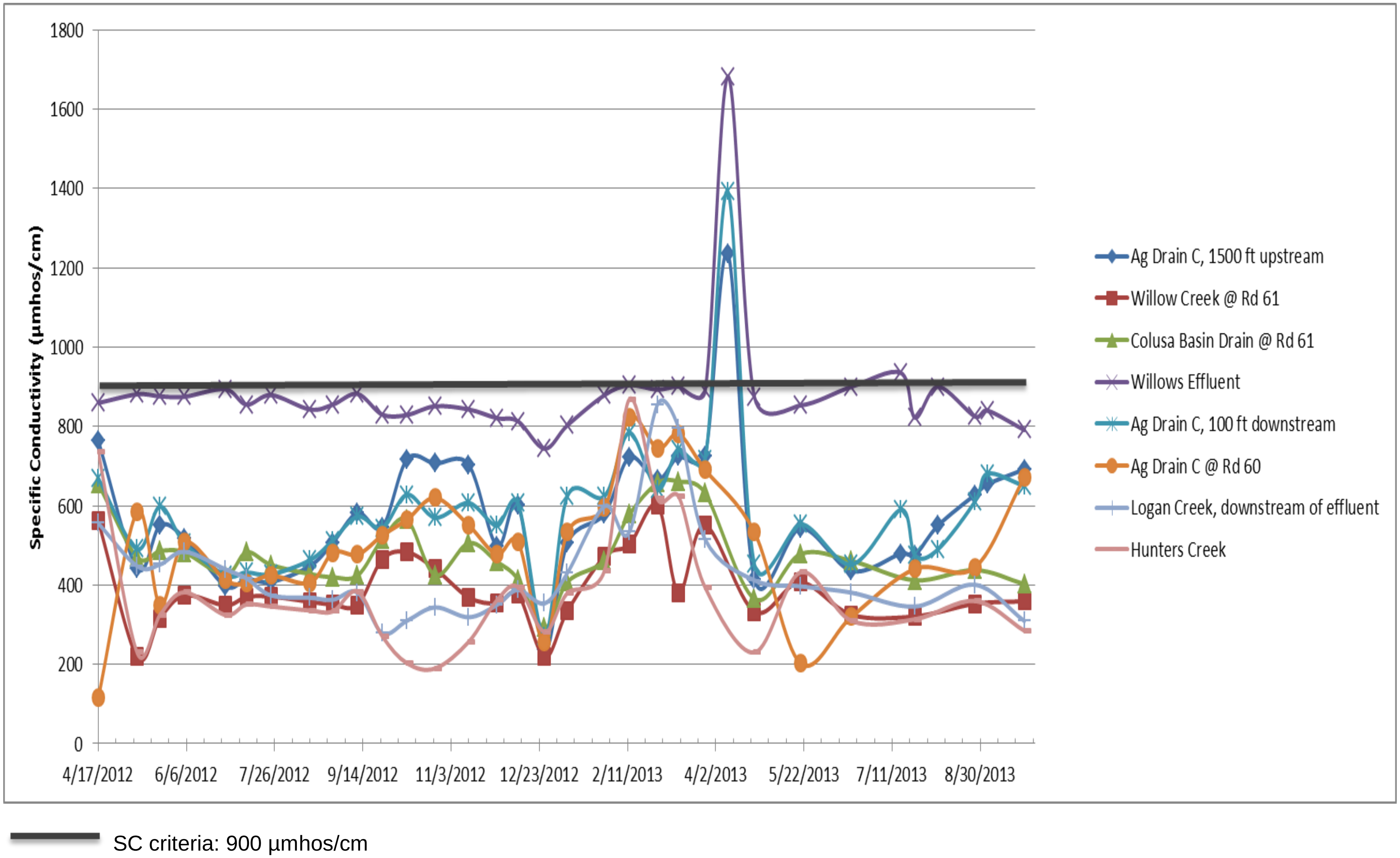
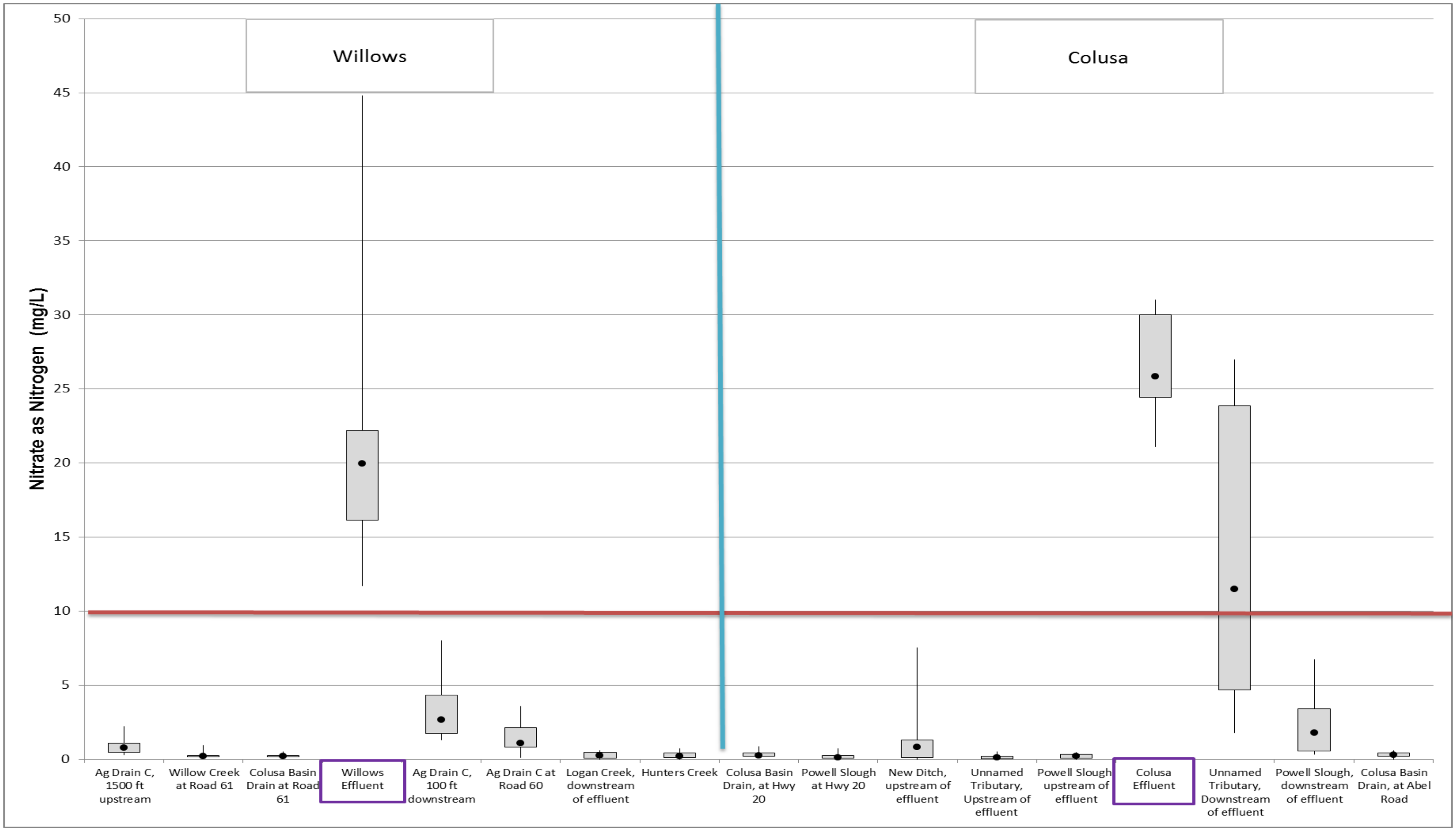


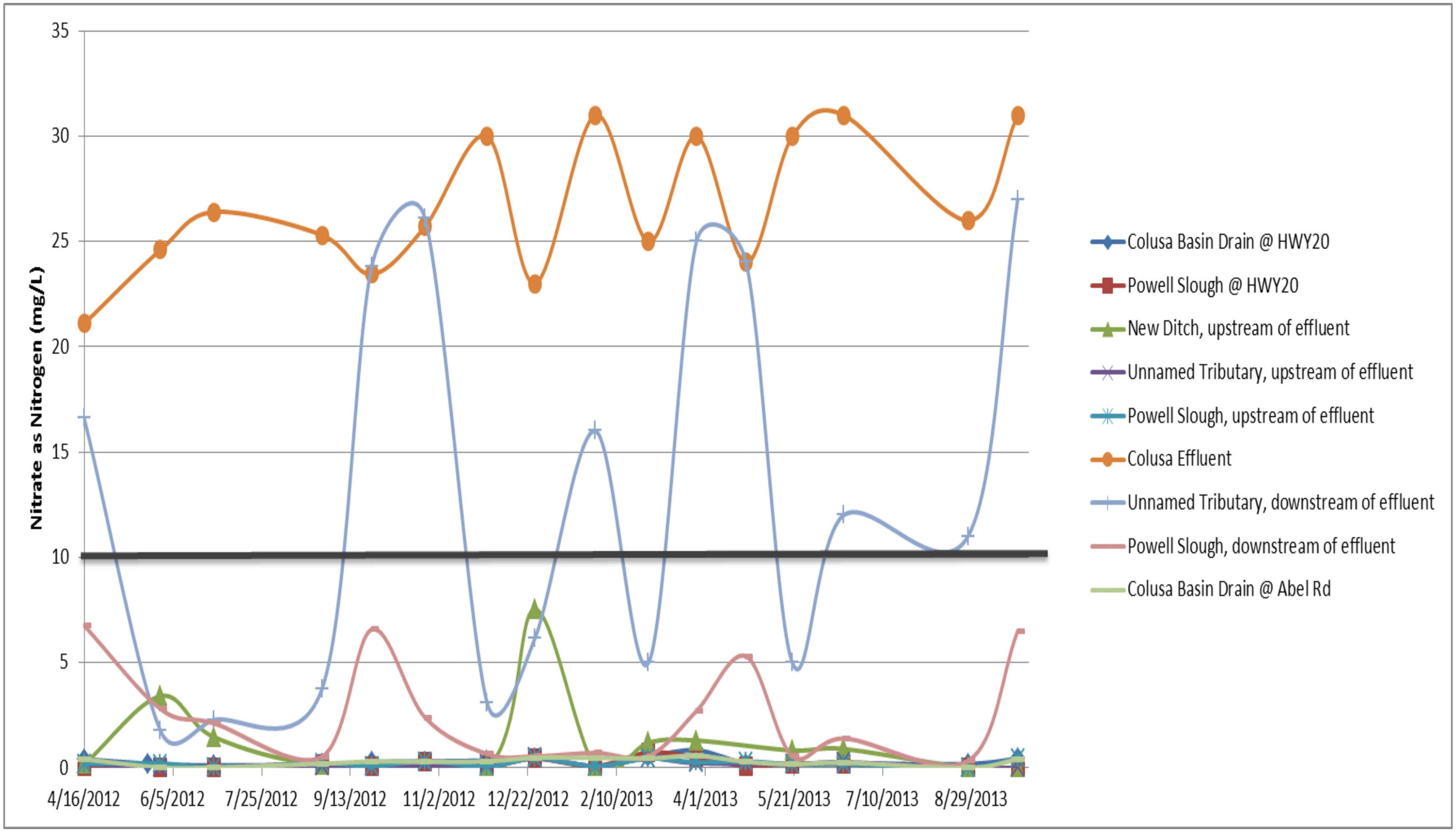
Figure 12 Summary Nitrate as Nitrogen: West Sacramento River Basin, April 2012—September 2013



Nitrate as Nitrogen criteria: 10 mg/L

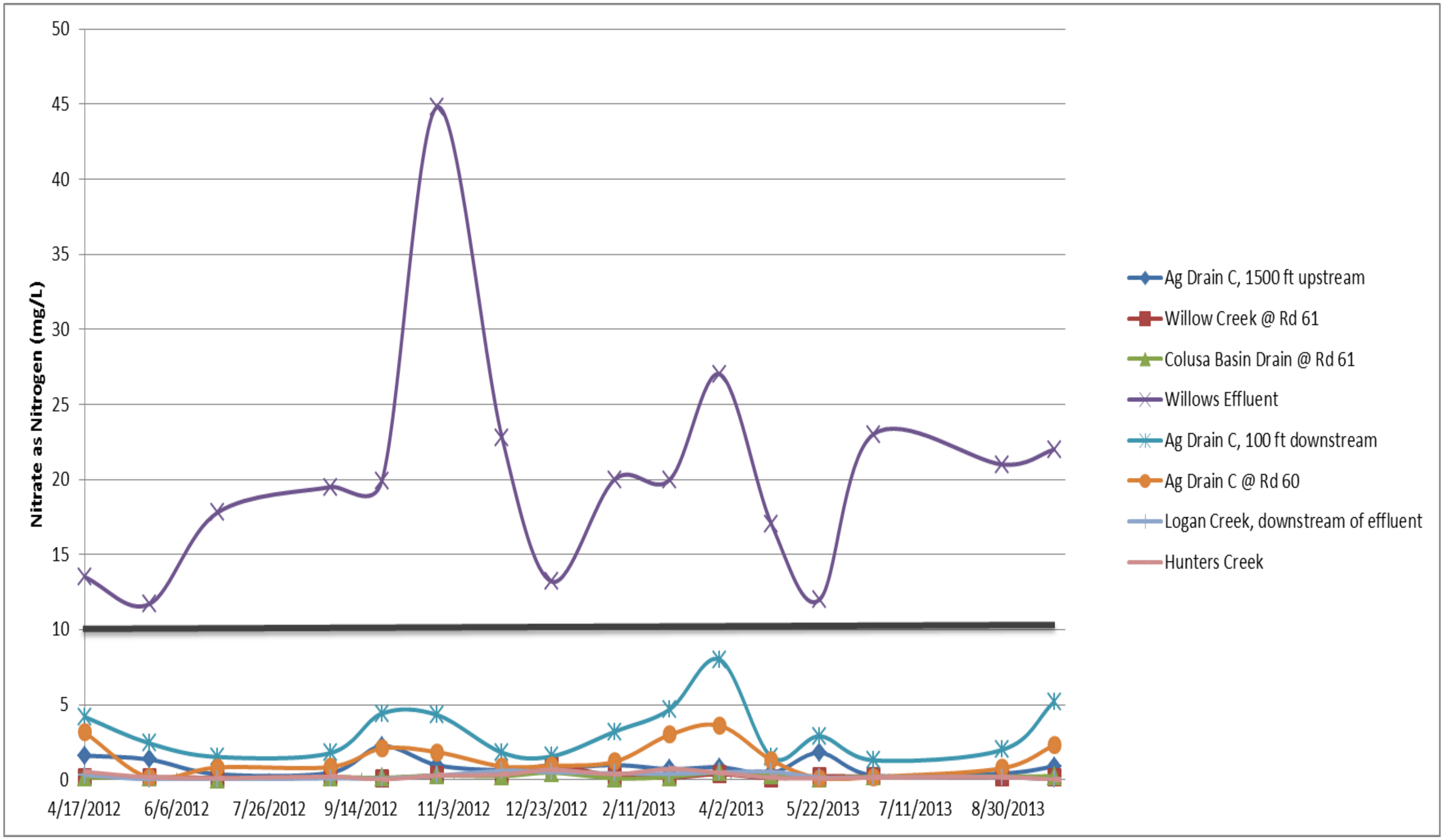
NOTE: Nitrate as nitrogen samples were discontinued from April 2013—June 2013 due to quarterly review

Figure 13 Colusa Study Area: Nitrate as Nitrogen, April 2012—September 2013



Nitrate as Nitrogen criteria: 10 mg/L

Figure 14 Willows Study Area: Nitrate as Nitrogen, April 2012—September 2013



Nitrate as Nitrogen criteria: 10 mg/L

Figure 15 Summary Total Arsenic: Colusa Study Area, April 2012—September 2013

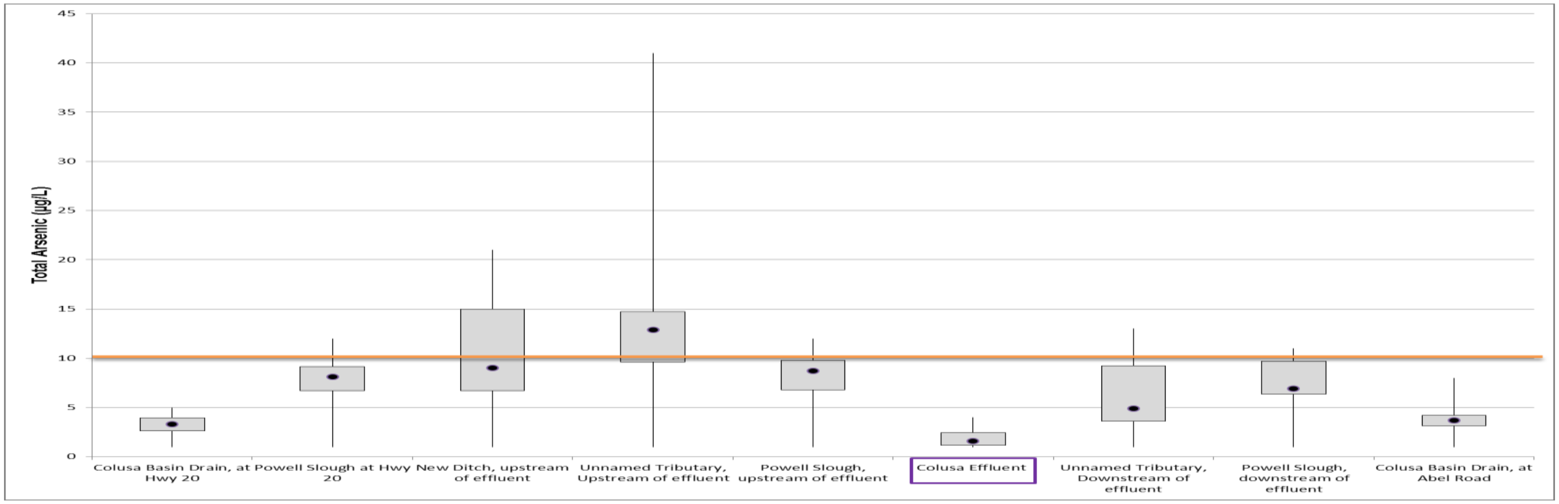
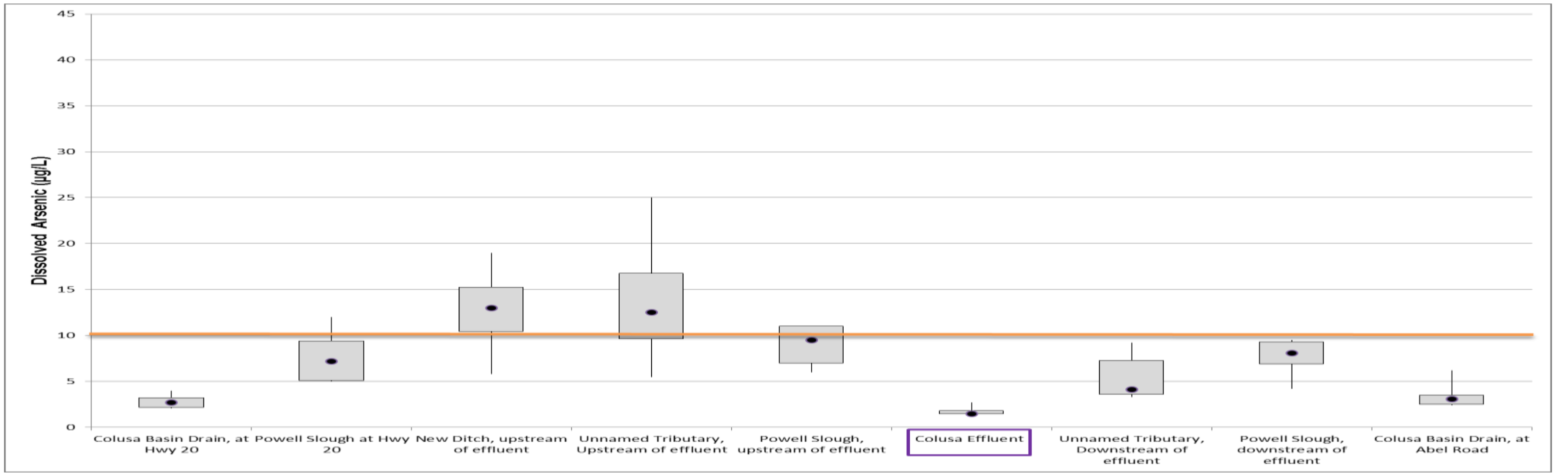


Figure 16 Summary Dissolved Arsenic: Colusa Study Area, April 2013—September 2013



Arsenic criteria: 10 µg/L

NOTE:

Dissolved Samples were only taken in 2013.

Weir was blocked on June 18, 2013 so no water was flowing downstream from the “Unnamed Tributary, upstream of effluent” site.

Figure 17 Colusa Study Area: Total Arsenic, April 2012—September 2013

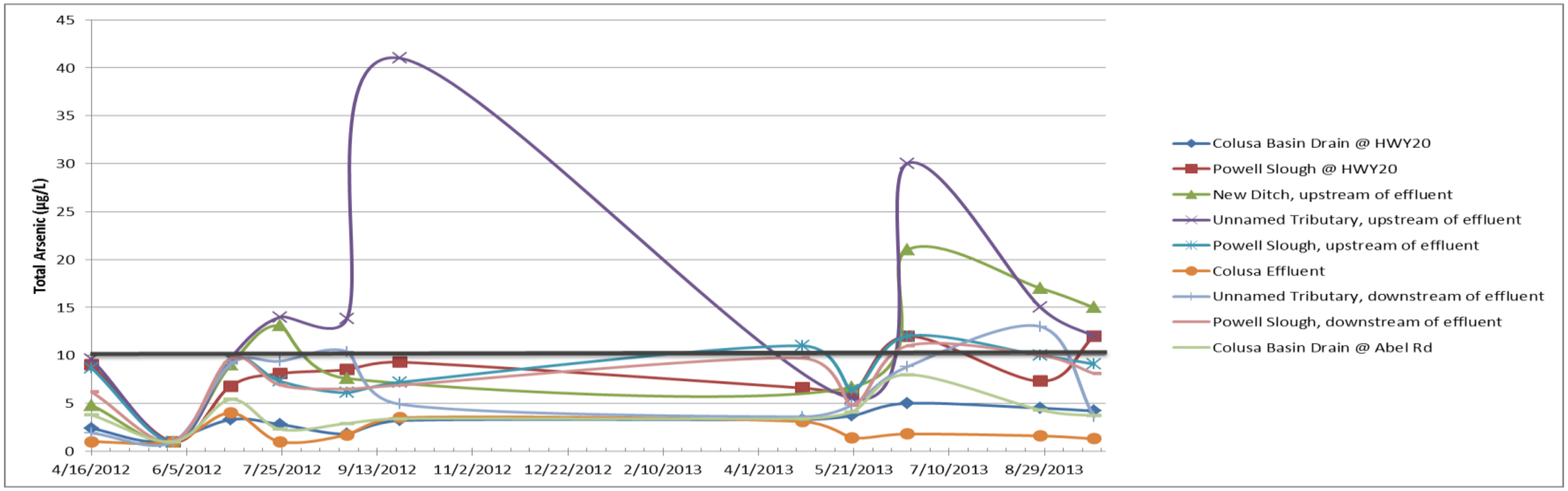
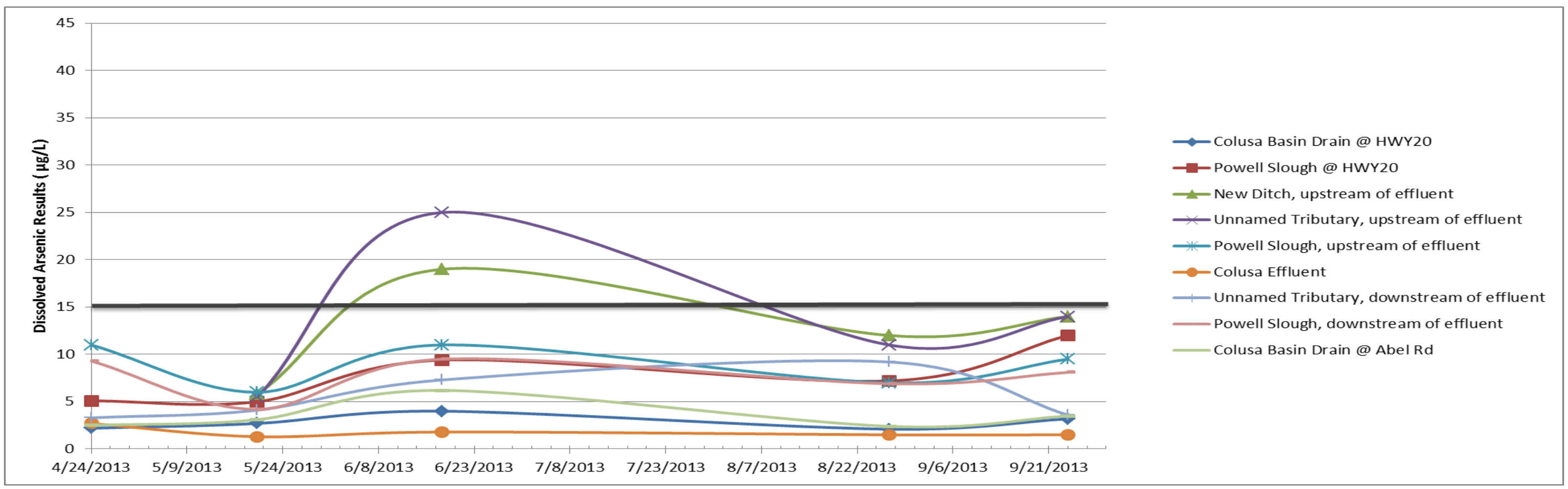


Figure 18 Colusa Study Area: Dissolved Arsenic, April 2013—September 2013



Arsenic criteria: 10 µg/L

NOTE:

Dissolved Samples were only taken in 2013.

Weir was blocked on June 18, 2013 so no water was flowing downstream from the “Unnamed Tributary, upstream of effluent” site.

Figure 19 Colusa Study Area: Turbidity, April 2012—September 2013

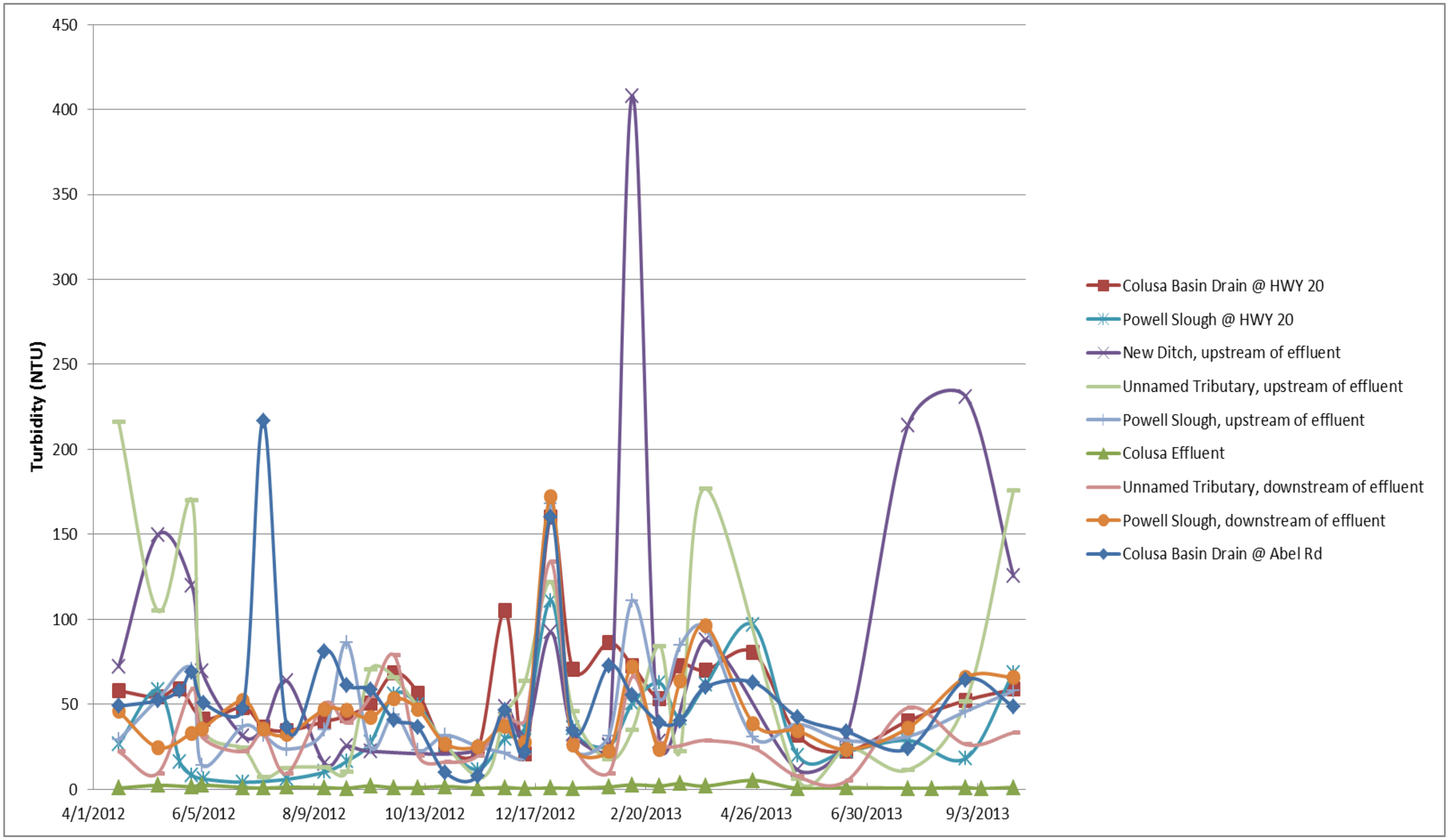
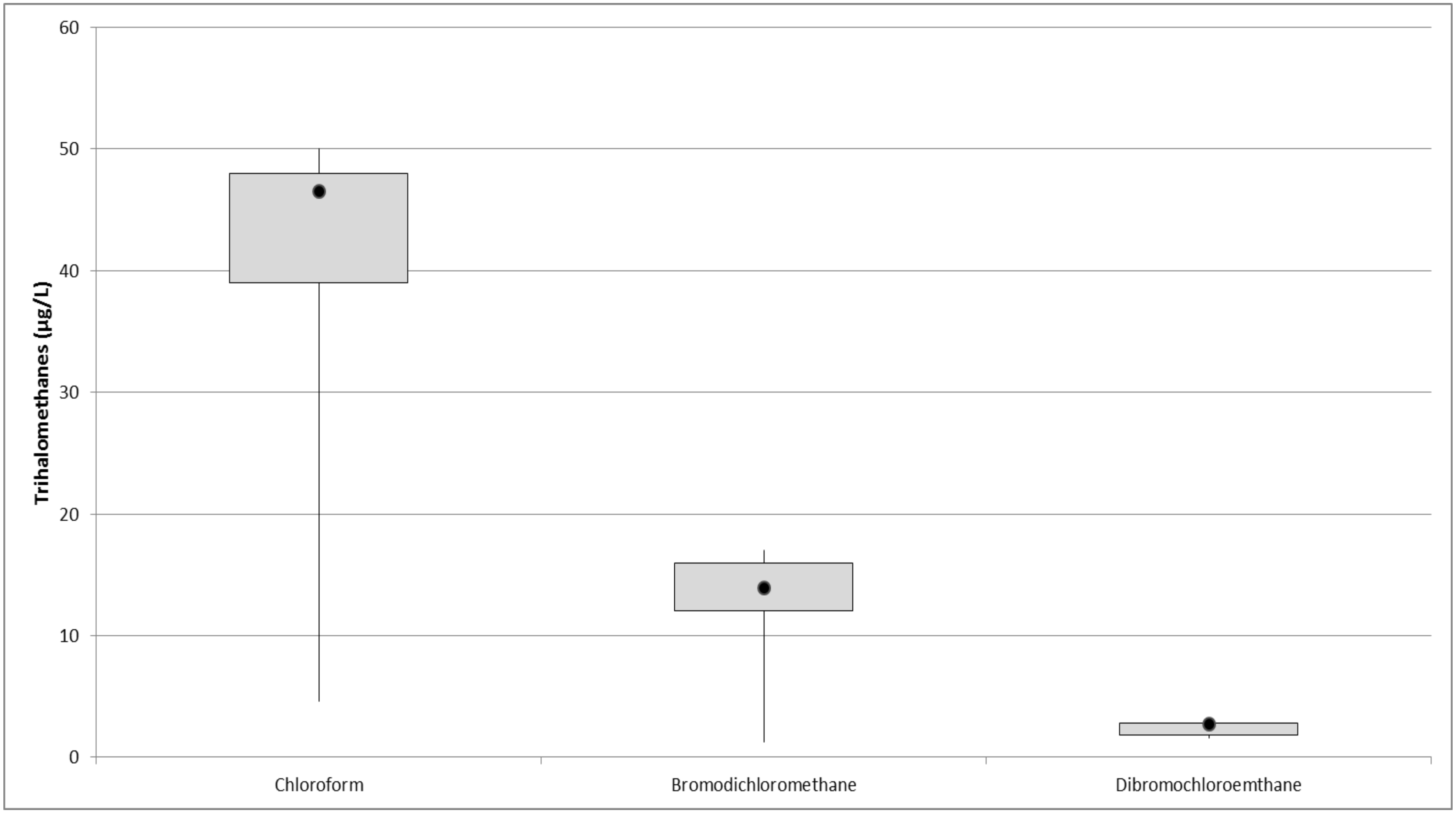
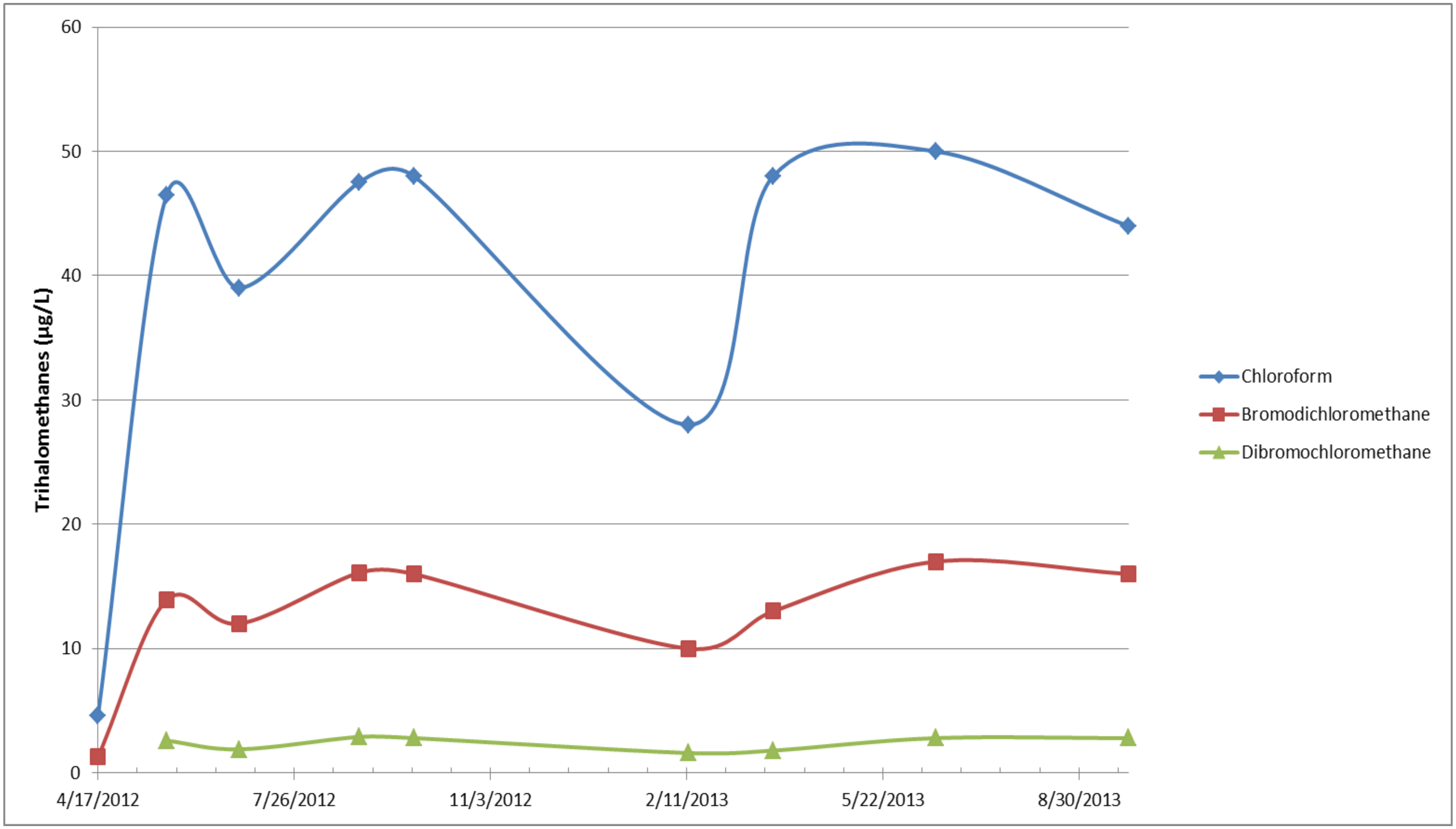


Figure 20 Summary Trihalomethanes: Willows' Effluent, April 2012—September 2013



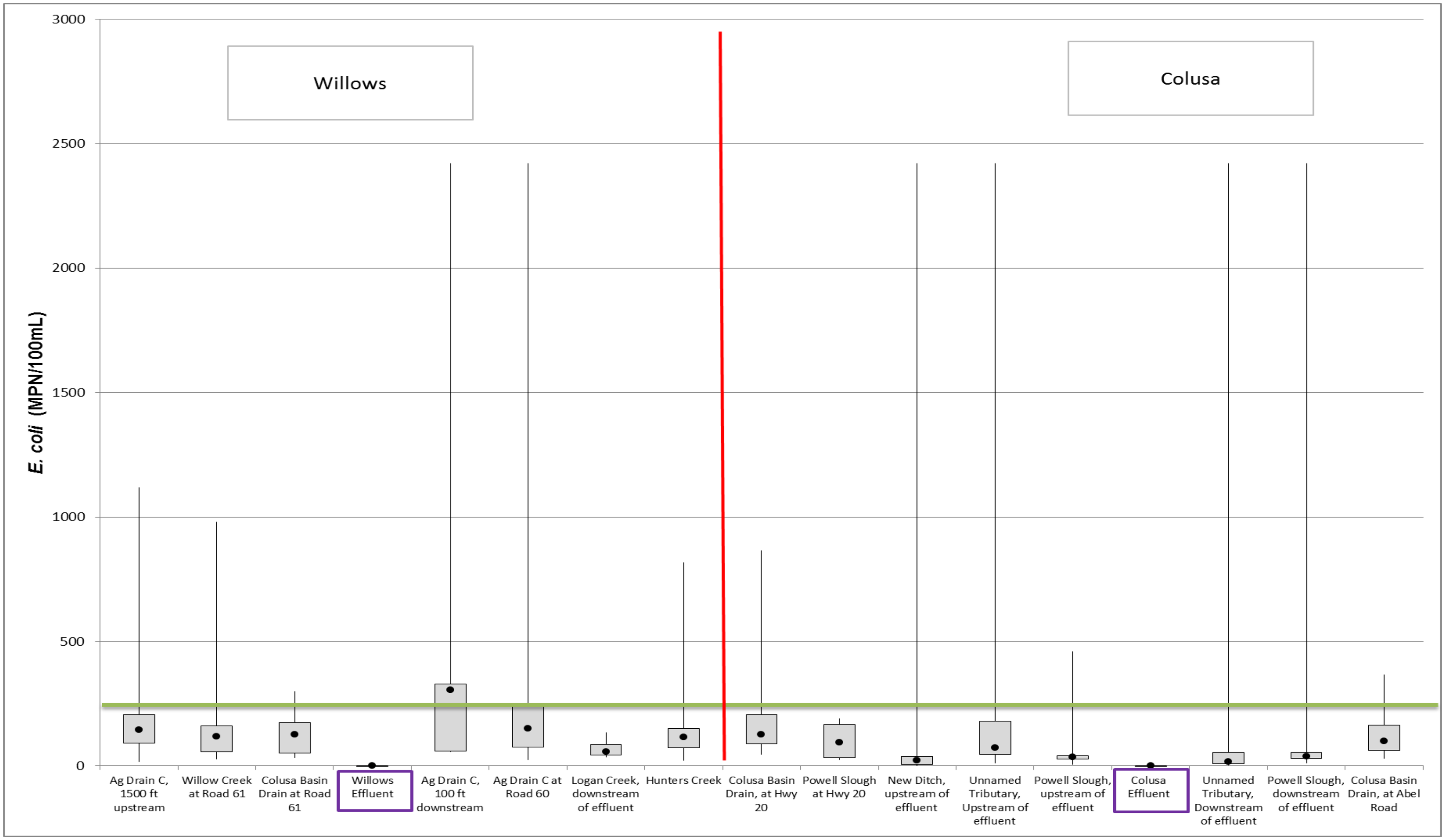
Chloroform criteria: 1.8 µg/L
Bromodichloromethane criteria: 0.56 µg/L
Dibromochloromethane criteria: 0.41 µg/L

Figure 21 Willows' Effluent: Trihalomethanes, April 2012—September 2013



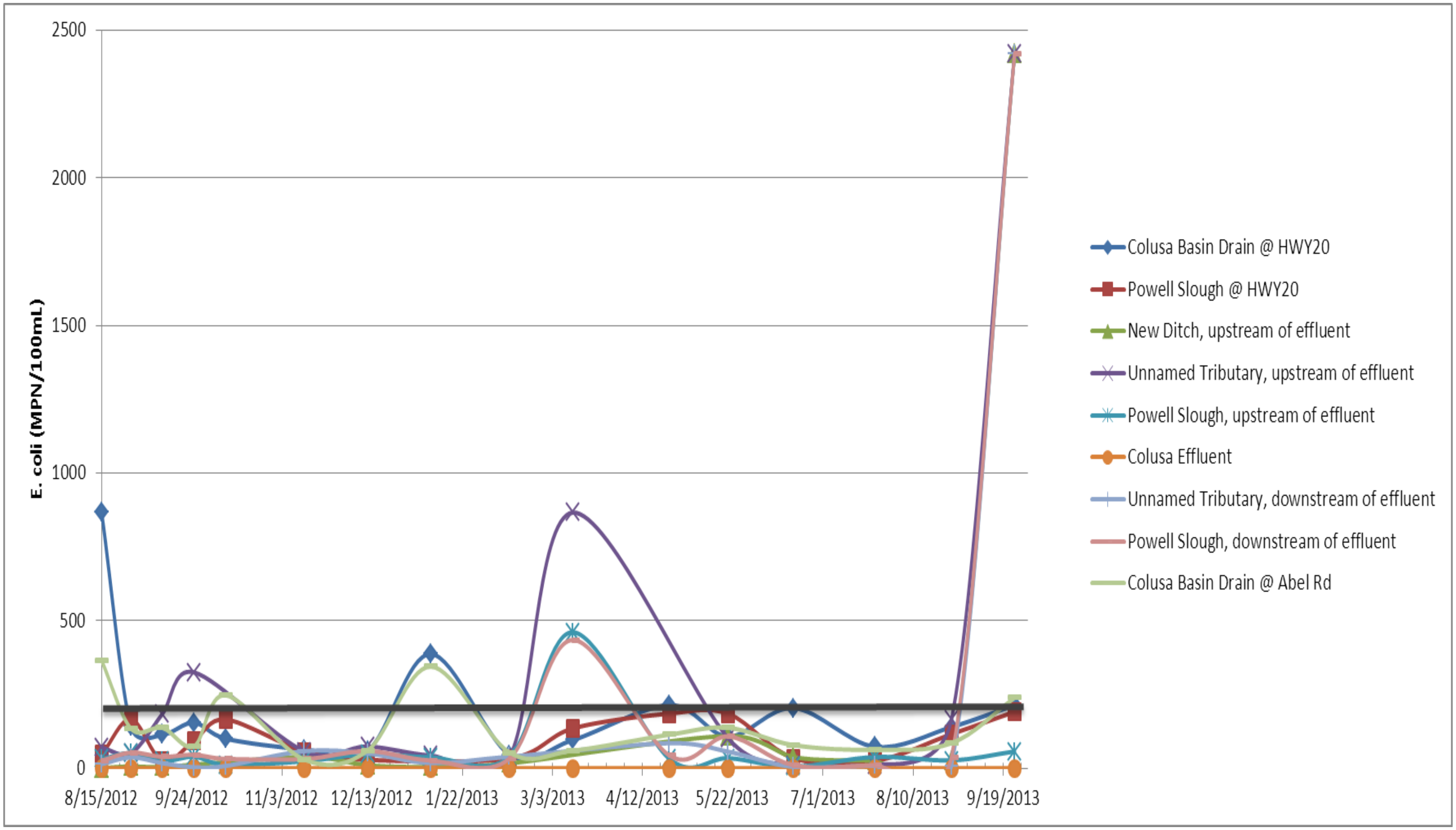
Chloroform criteria: 1.8 µg/L
Bromodichloromethane criteria: 0.56 µg/L
Dibromochloromethane criteria: 0.41 µg/L

Figure 22 Summary *E. coli*: West Sacramento River Basin, August 2012—September 2013



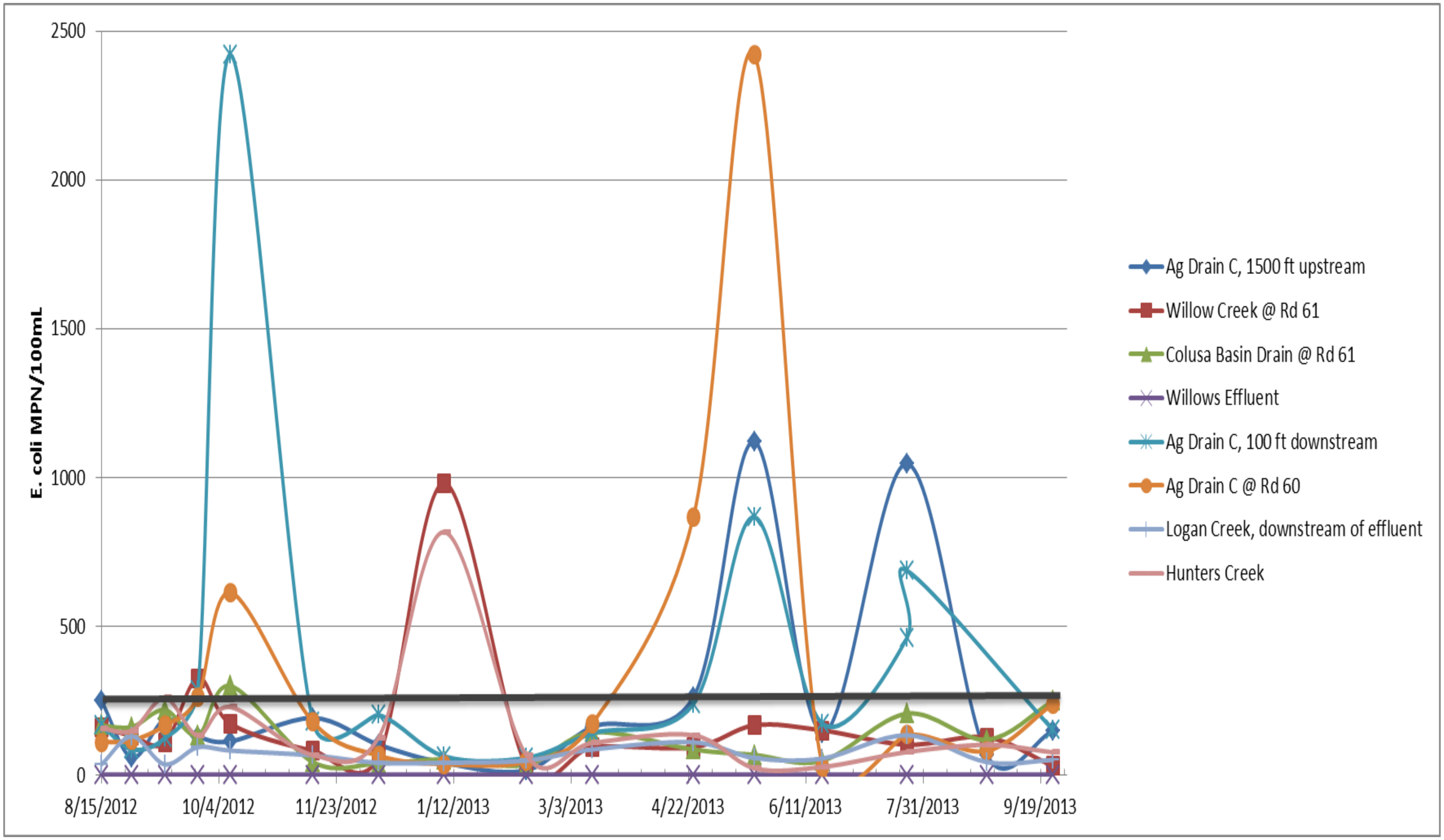
E. coli criteria: 235 MPN/100mL

Figure 23 Colusa Study Area: *E. coli*, August 2012—September 2013



E. coli criteria: 235 MPN/100mL

Figure 24 Willows Study Area: *E. coli*, August 2012—September 2013



E. coli criteria: 235 MPN/100mL

Figure 25 Summary Specific Conductance: East Sacramento River Basin, April 2012—September 2013

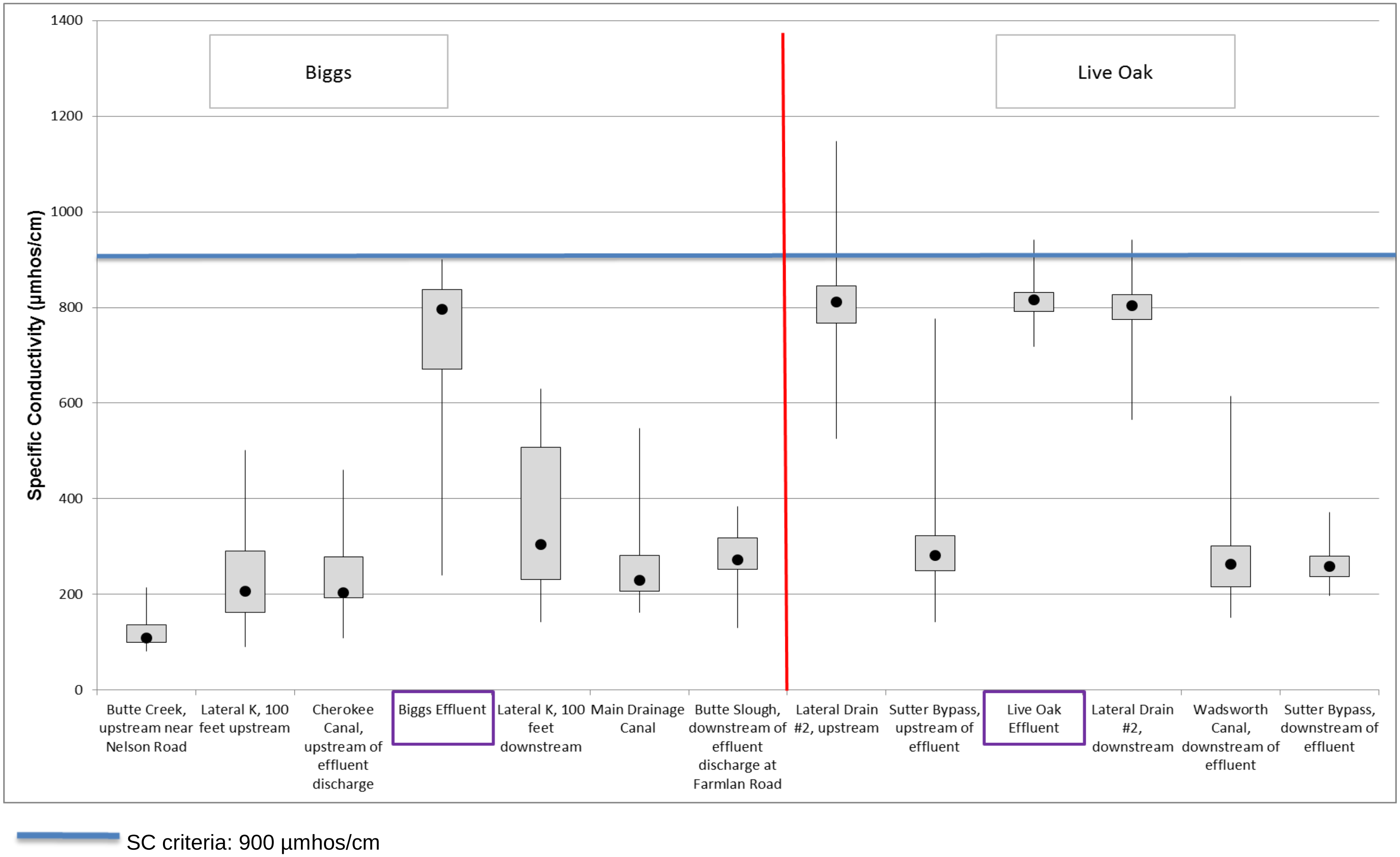
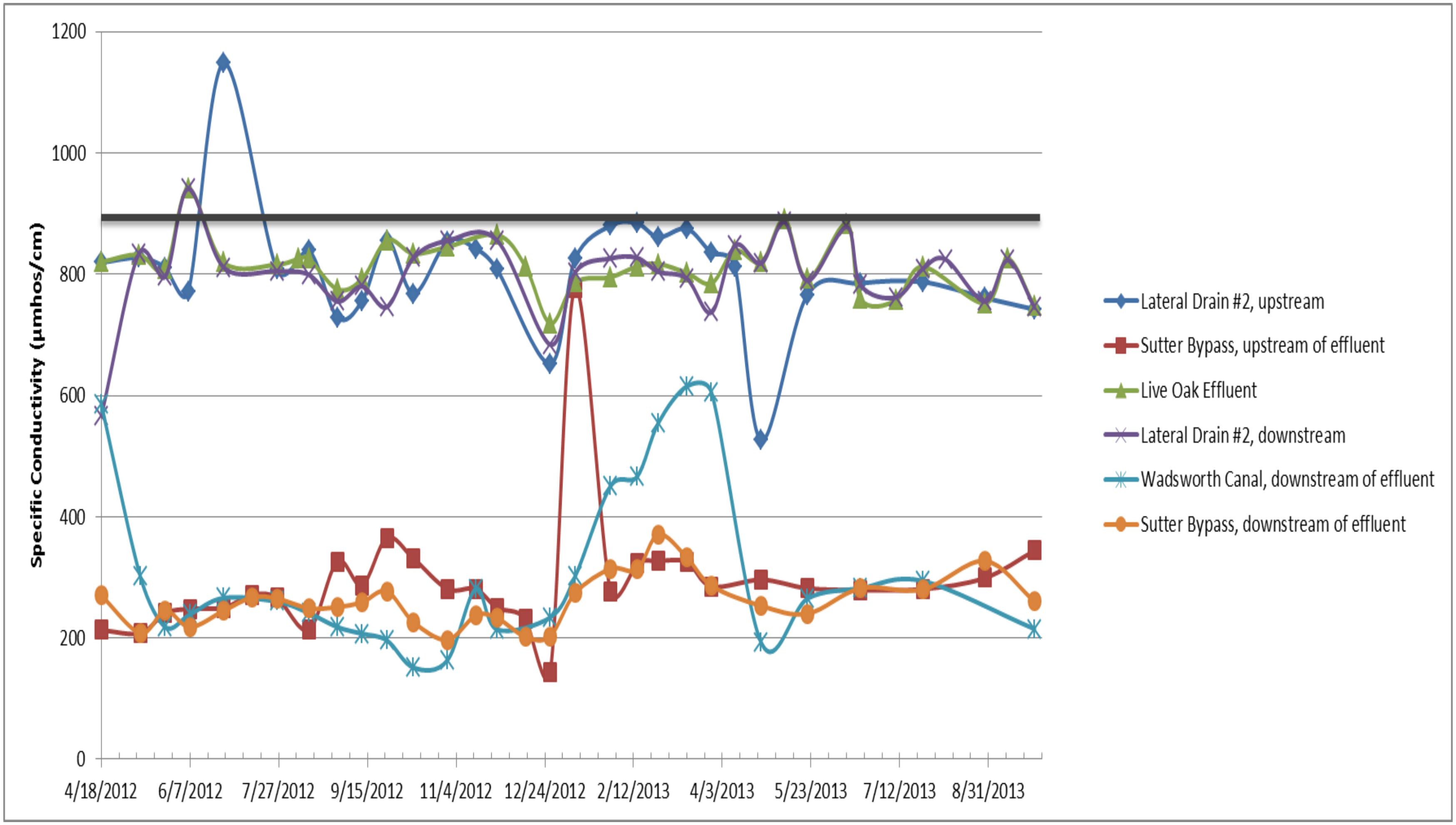
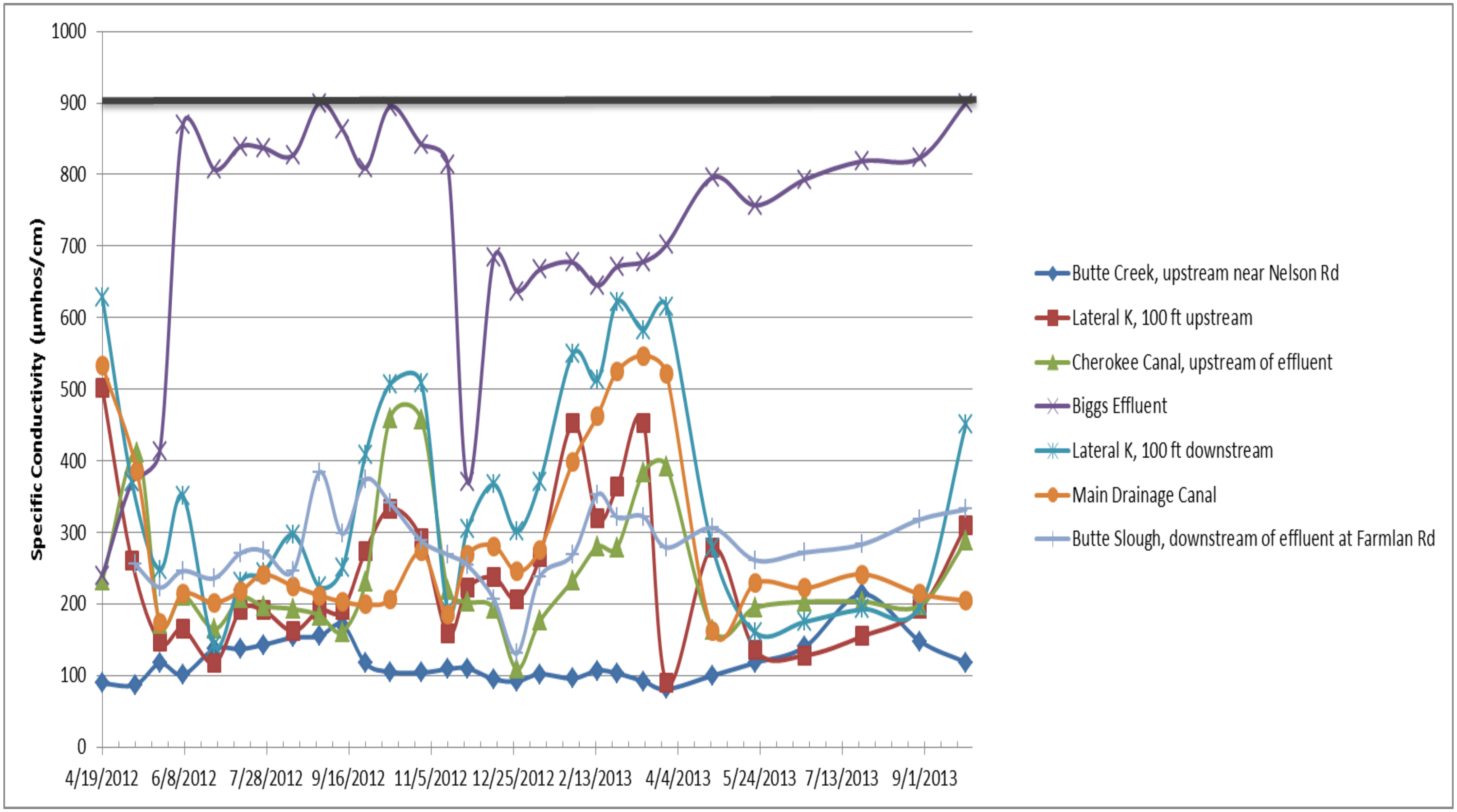


Figure 26 Live Oak Study Area: Specific Conductance, April 2012—September 2013



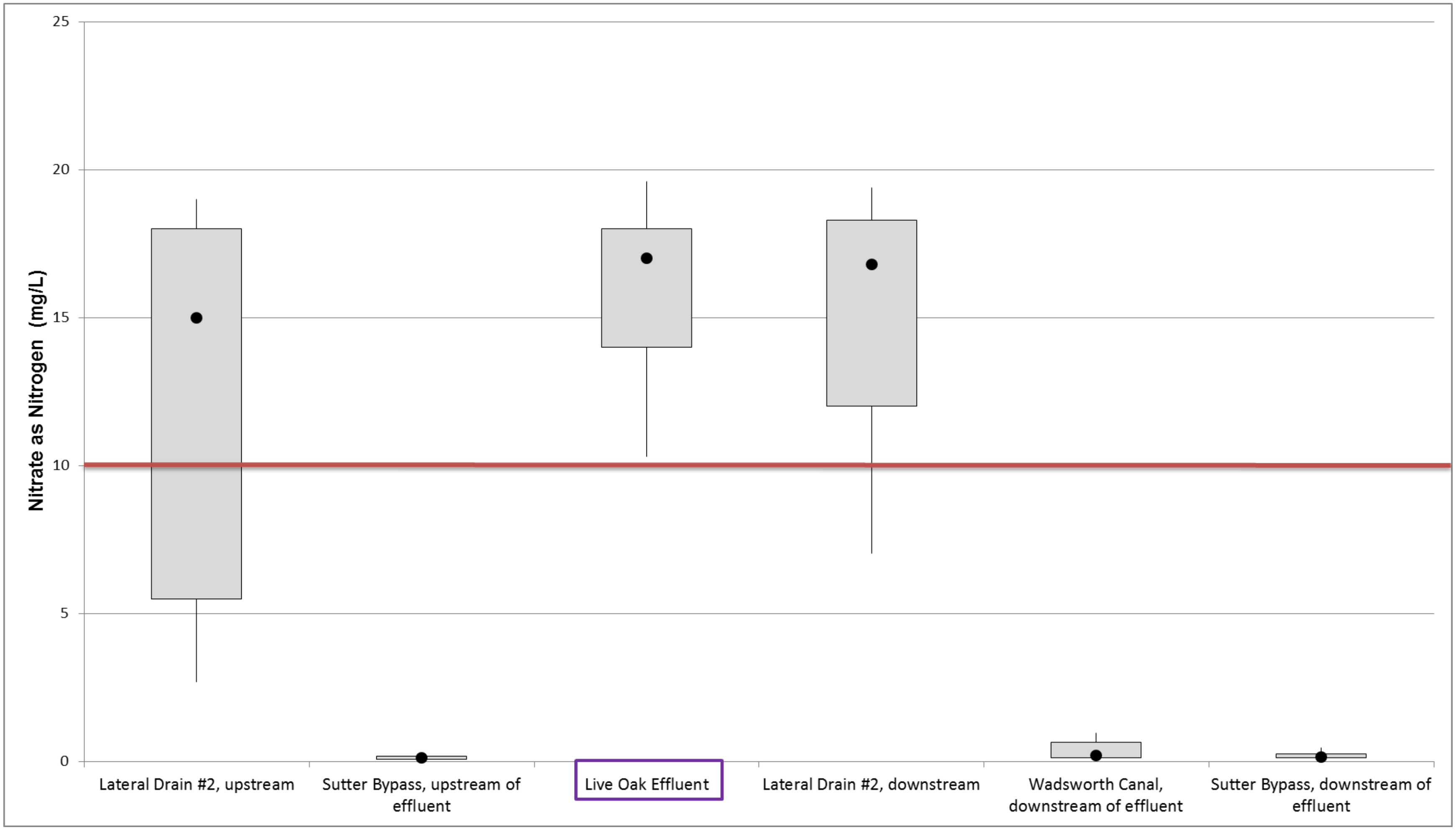
SC criteria: 900 µmhos/cm

Figure 27 Biggs Study Area: Specific Conductance, April 2012—September 2013



SC criteria: 900 µmhos/cm

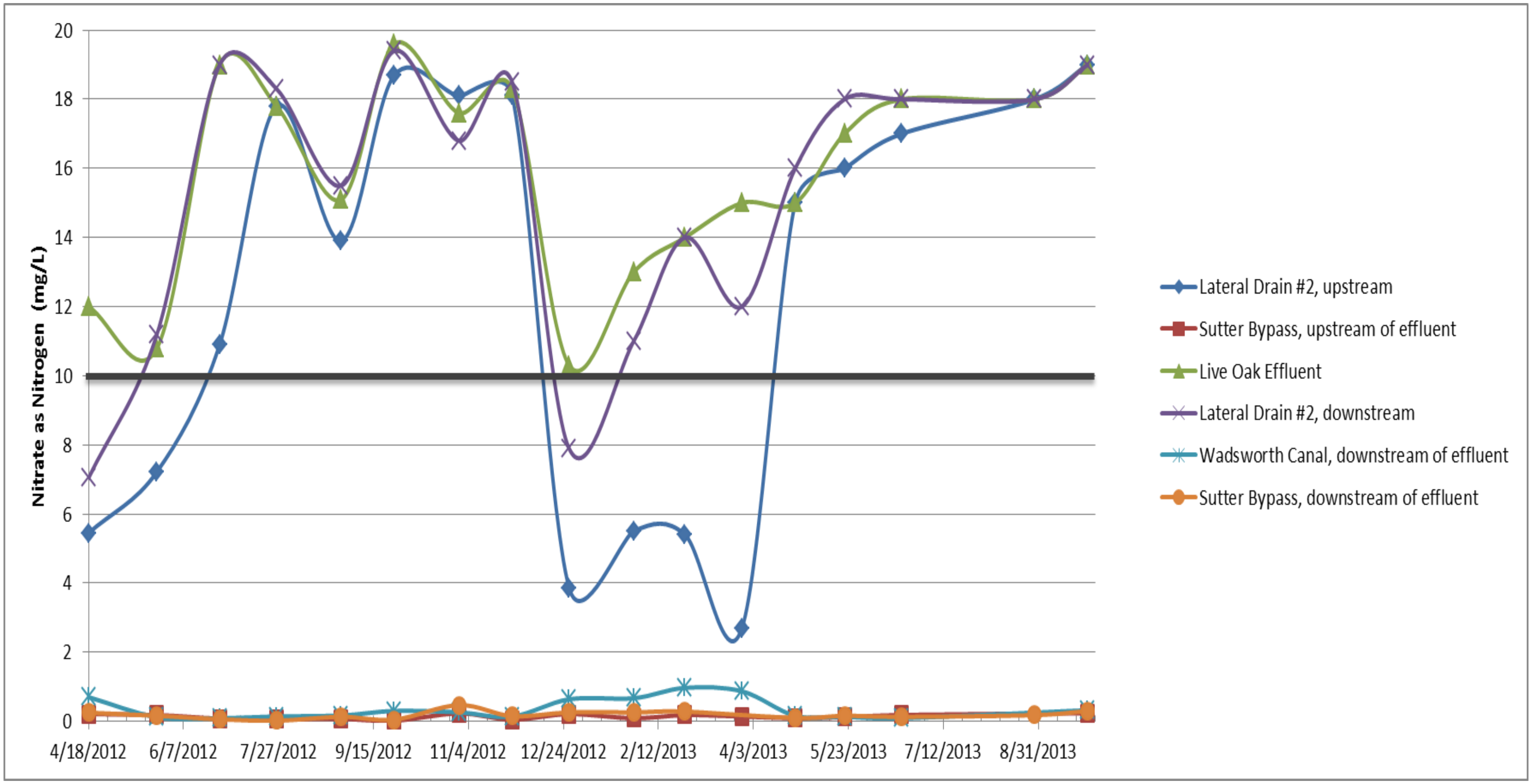
Figure 28 Summary Nitrate as Nitrogen: Live Oak Study Area, April 2012—September 2013



Nitrate as Nitrogen criteria: 10 mg/L

NOTE: Nitrate as nitrogen samples were discontinued from April 2013—June 2013 due to quarterly review.

Figure 29 Live Oak Study Area: Nitrate as Nitrogen, April 2012—September 2013



Nitrate as Nitrogen criteria: 10 mg/L

Figure 30 Summary Total Arsenic: Live Oak Study Area, April 2012—September 2013

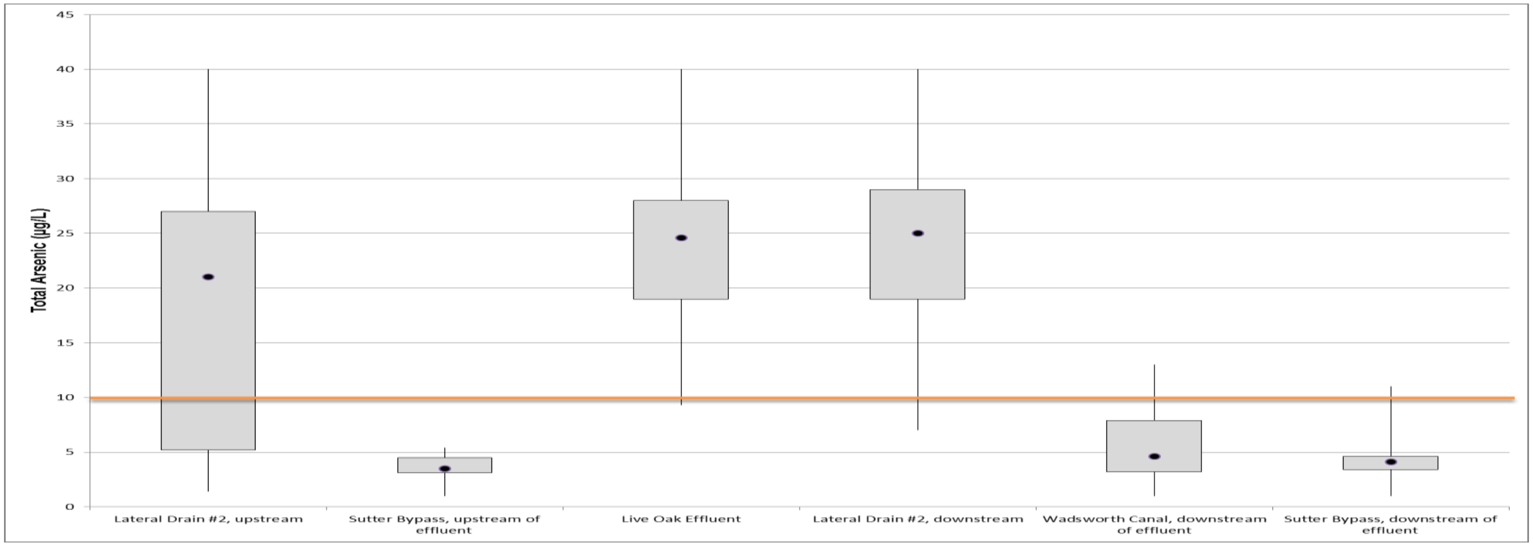
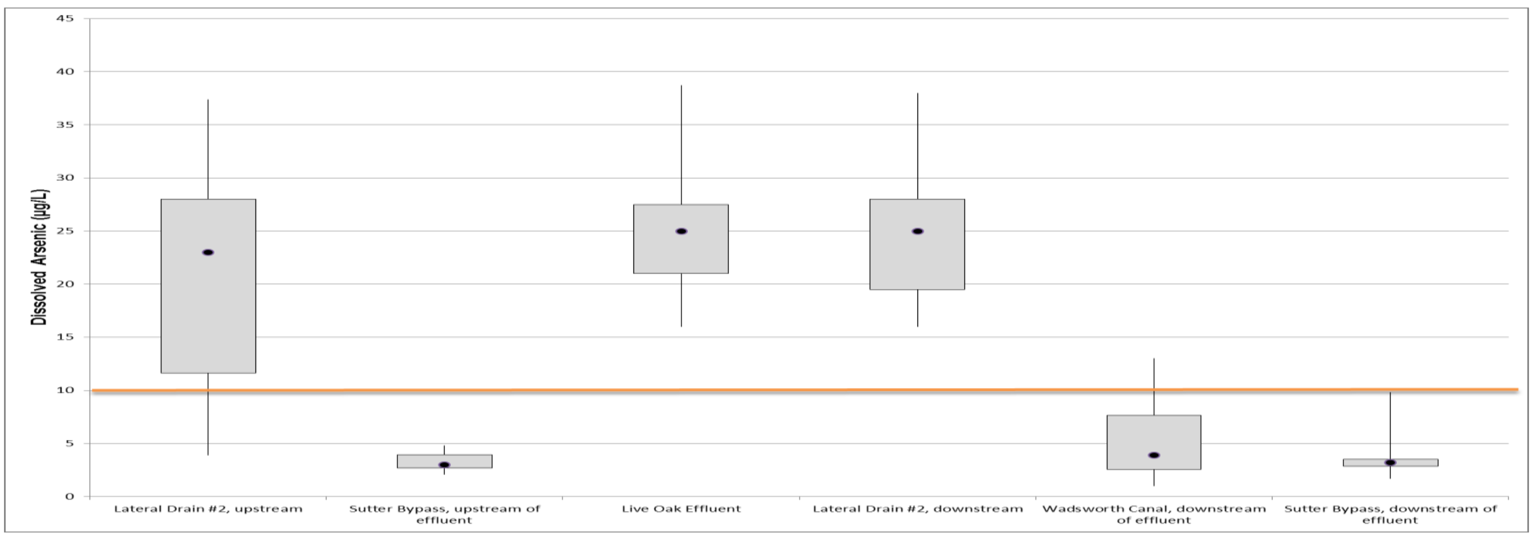


Figure 31 Summary Dissolved Arsenic: Live Oak Study Area, April 2012—September 2013



Arsenic criteria: 10 µg/L

Figure 32 Live Oak Study Area: Total Arsenic, April 2012—September 2013

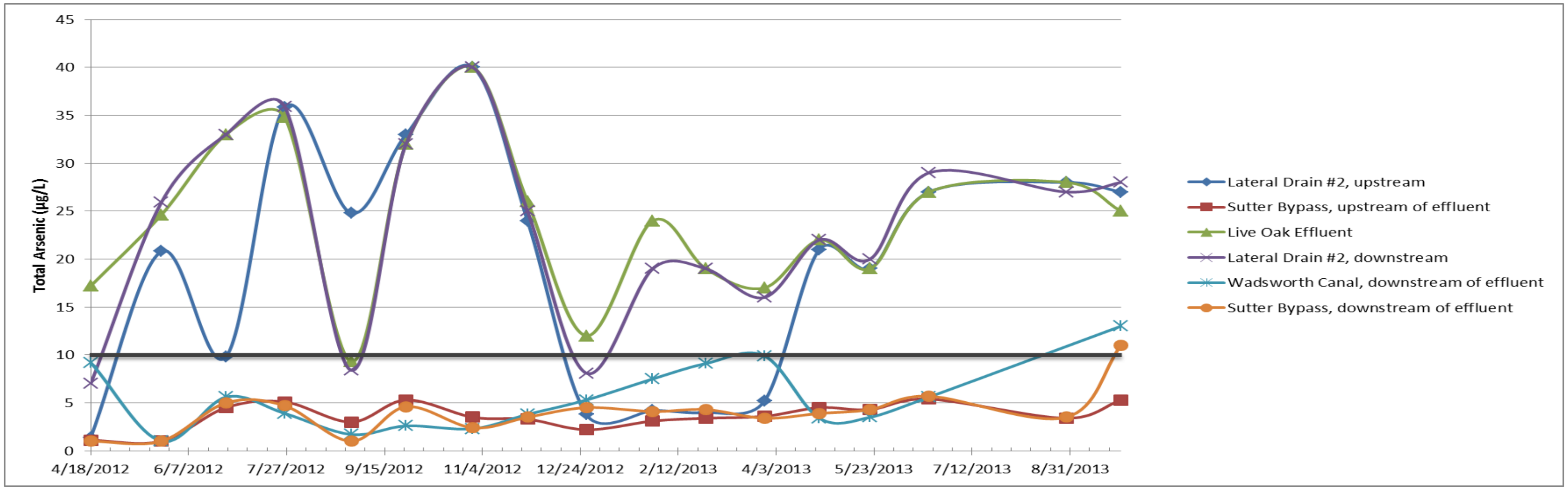
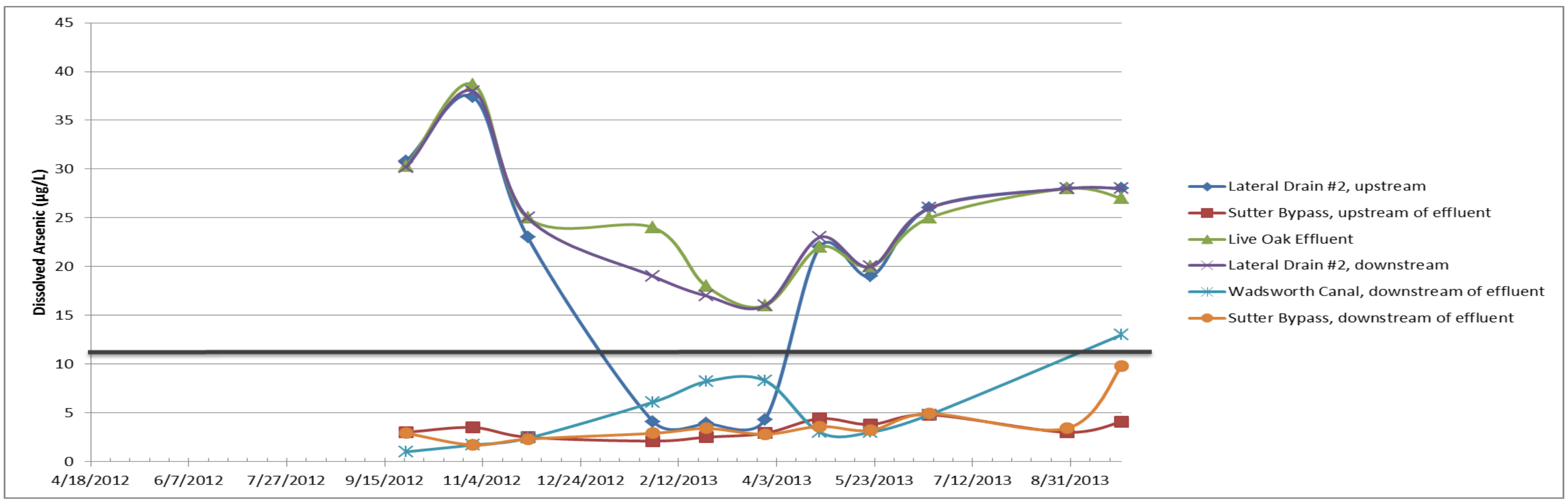


Figure 33 Live Oak Study Area: Dissolved Arsenic, April 2012—September 2013



Arsenic criteria: 10 µg/L

Figure 34 Live Oak Study Area: Turbidity, April 2012—September 2013

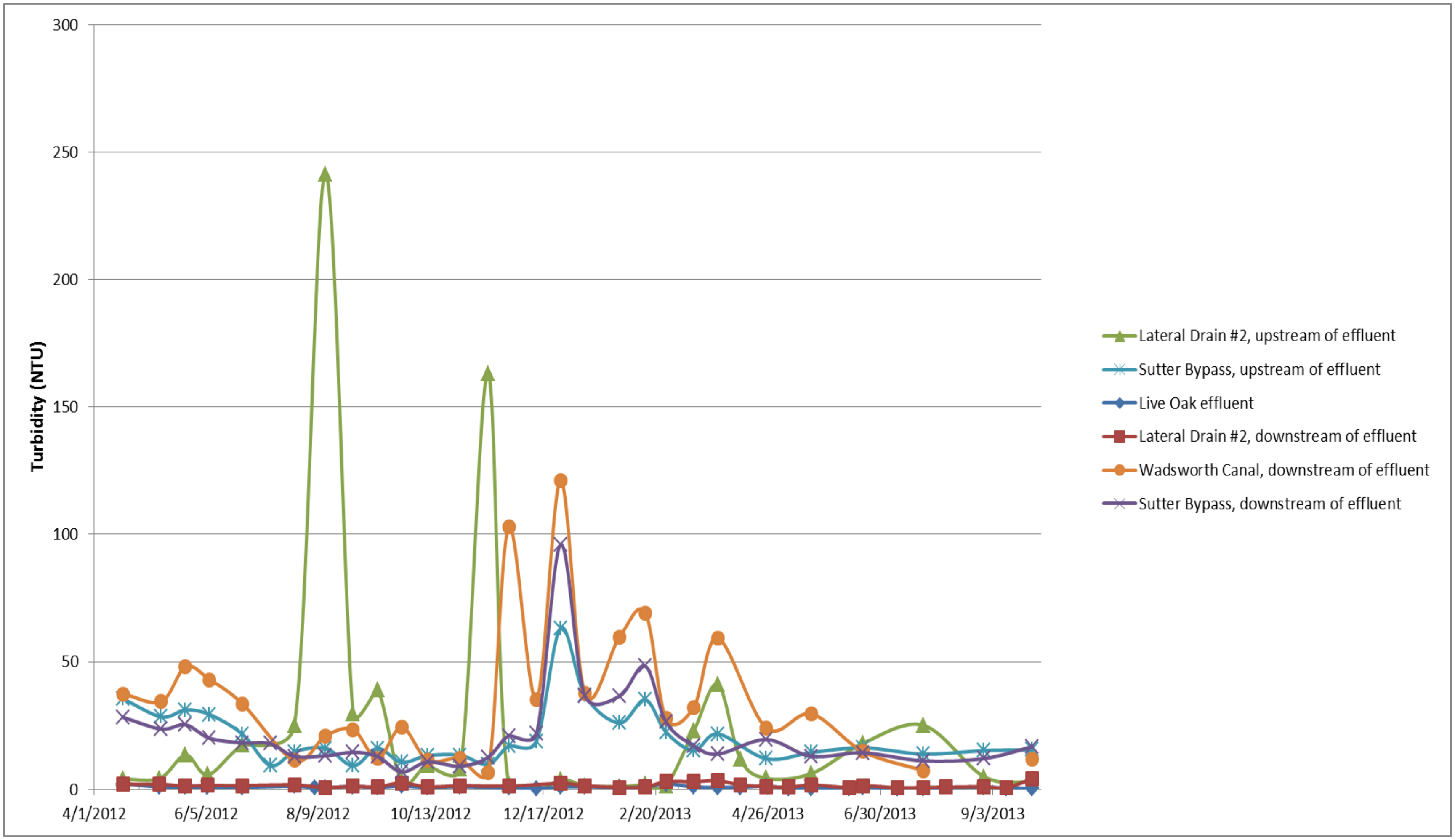


Figure 35 Summary Ammonia as Nitrogen: Biggs Study Area, April 2012—September 2013

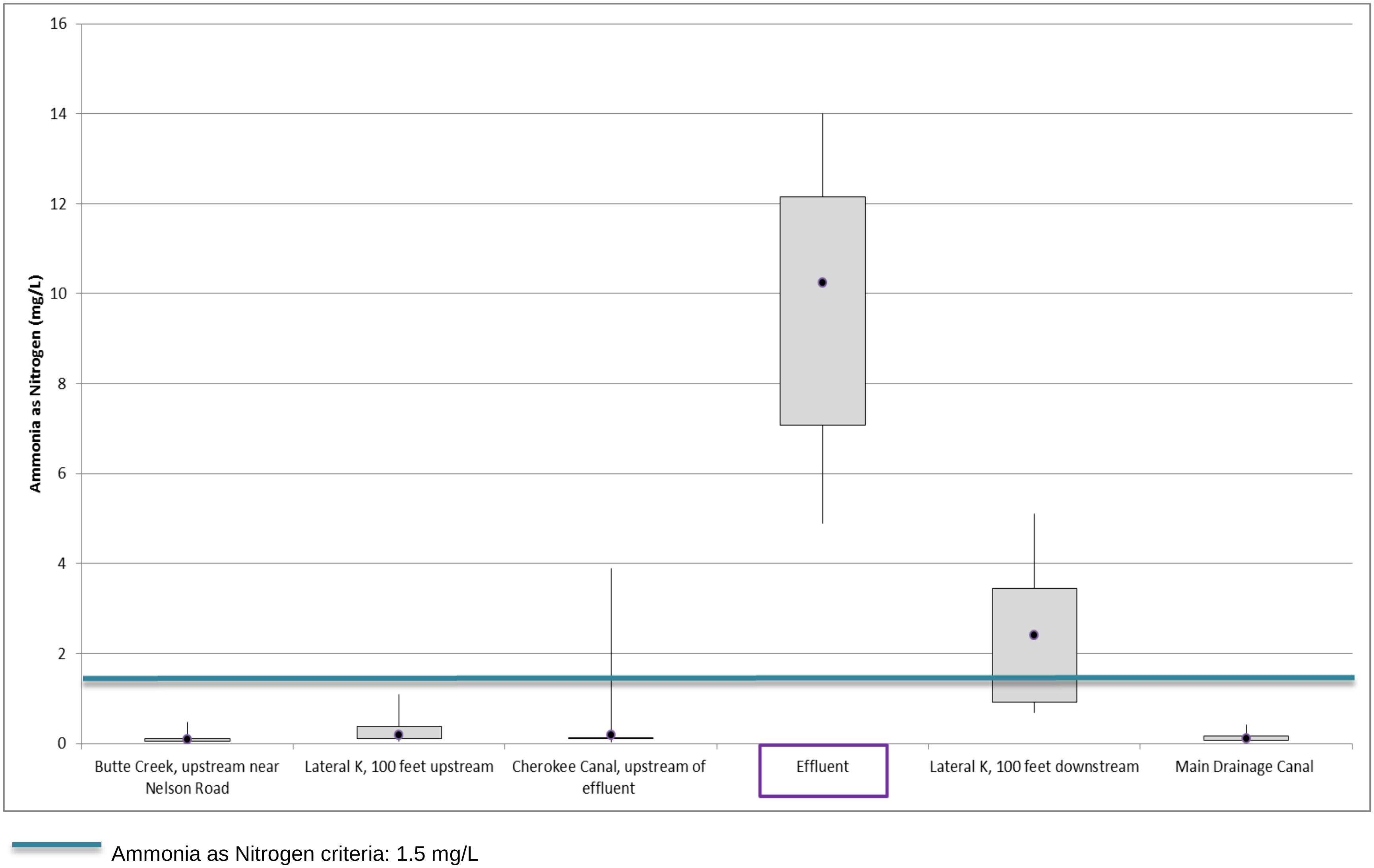
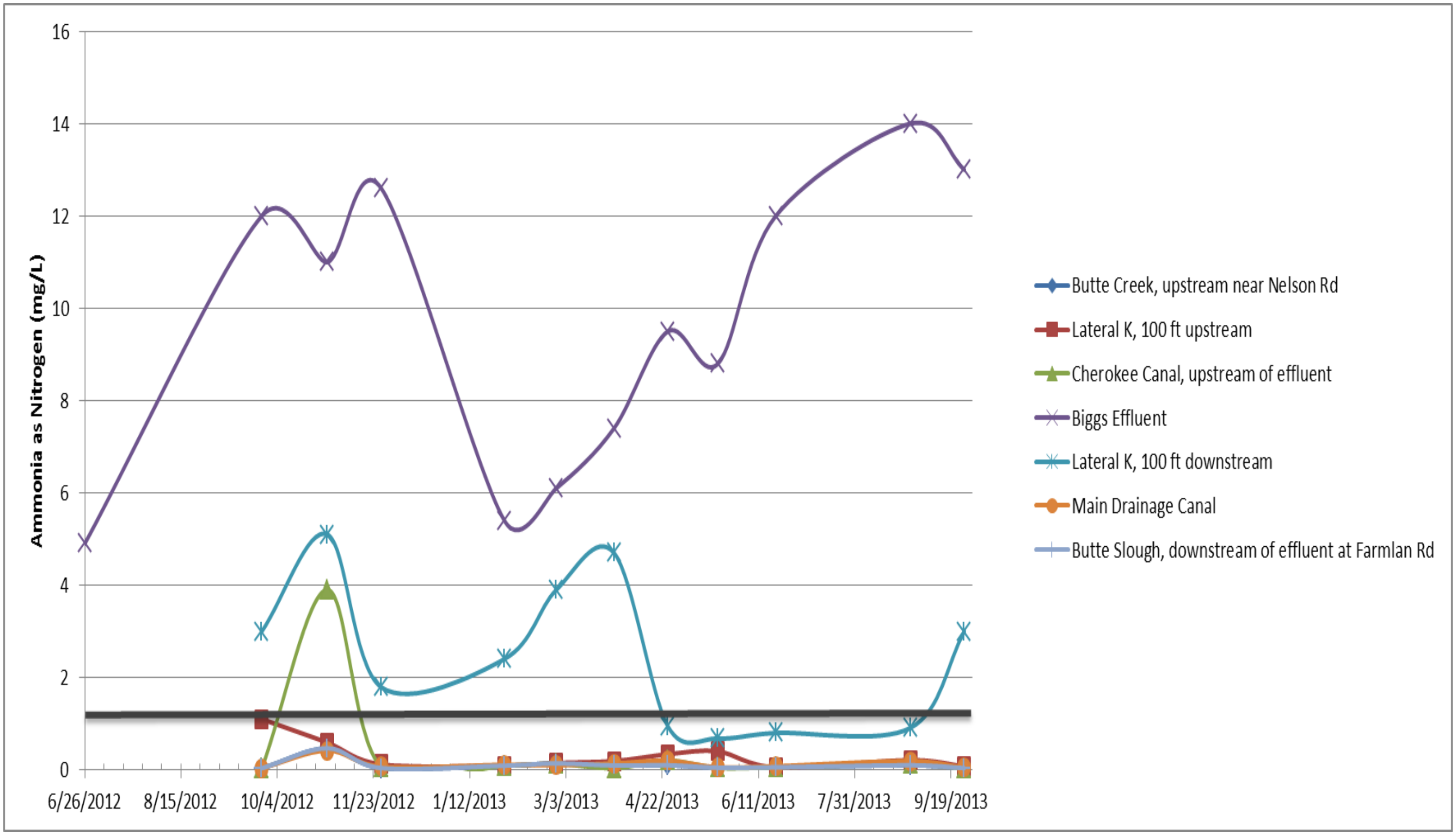


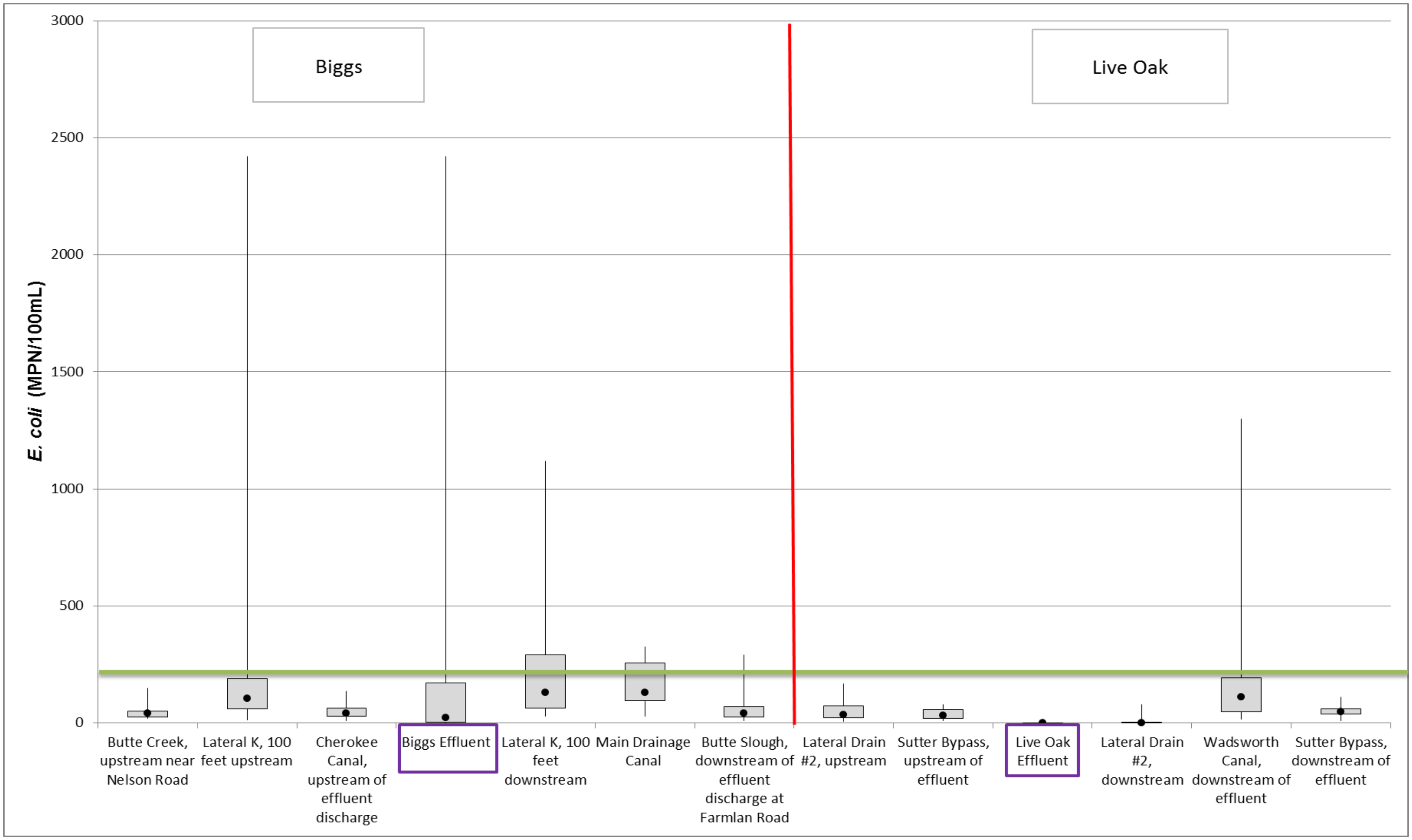
Figure 36 Biggs Study Area: Ammonia as Nitrogen, April 2012—September 2013



Ammonia as Nitrogen criteria: 1.5 mg/L

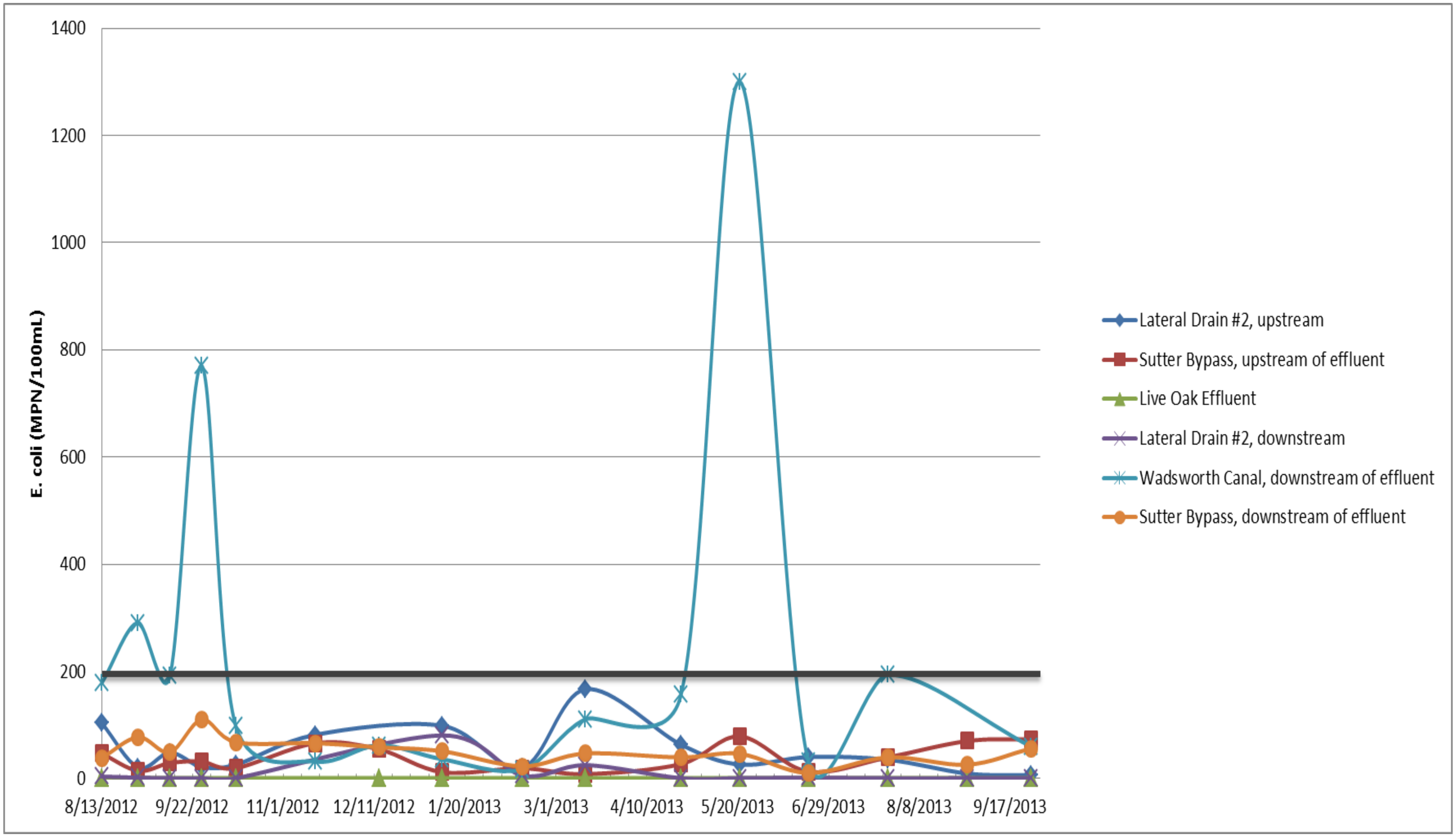
NOTE: Butte Creek, upstream near Nelson Road shared very similar concentration patterns as Lateral K upstream, Main Drainage Canal, and Butte Slough.

Figure 37 Summary *E. coli*: East Sacramento River Basin, August 2012—September 2013



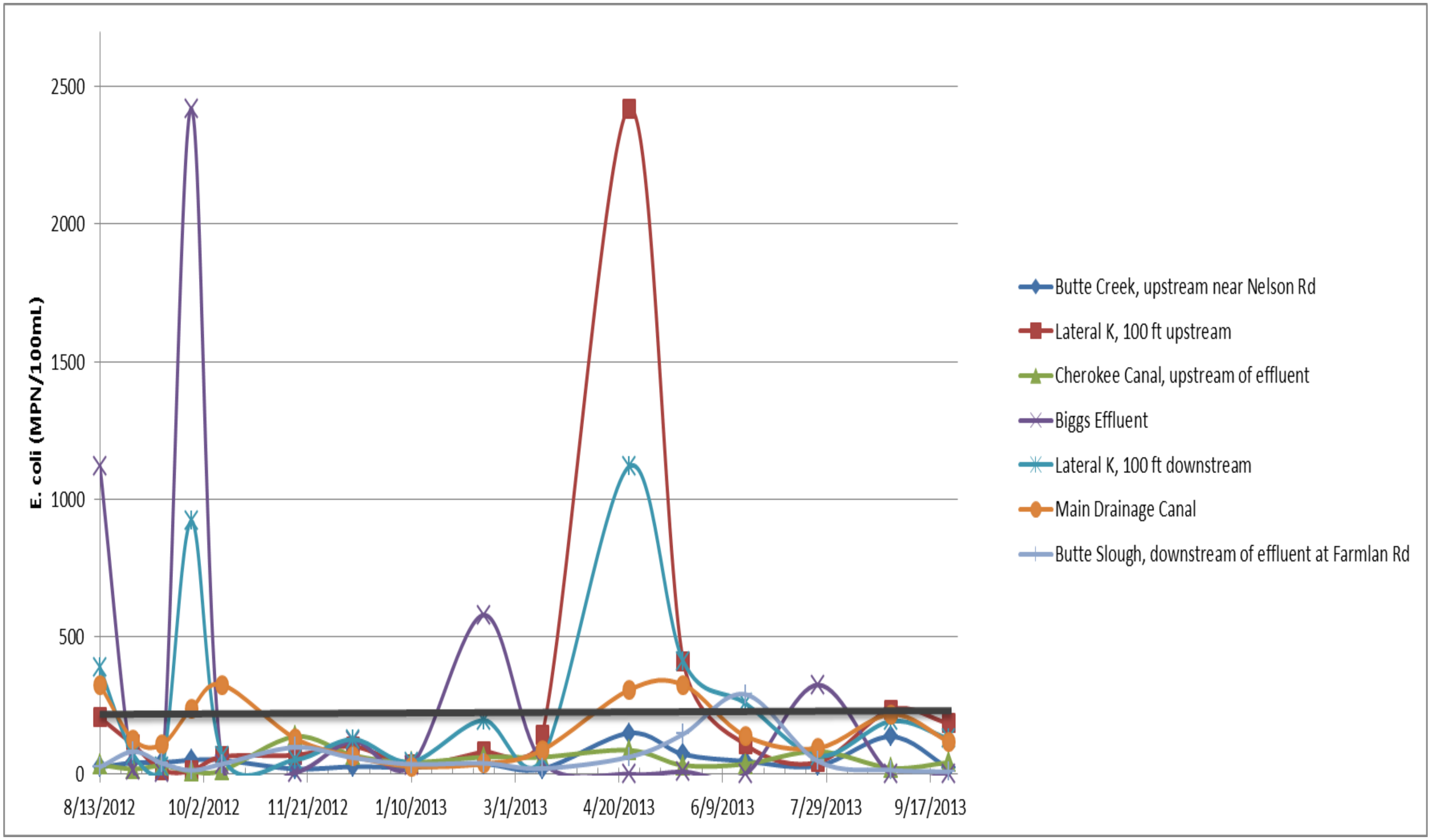
E. coli criteria: 235 MPN/100mL

Figure 38 Live Oak Study Area: *E. coli*, August 2012—September 2013



E. coli criteria: 235 MPN/100mL

Figure 39 Biggs Study Area: *E. coli*, August 2012—September 2013



E. coli criteria: 235 MPN/100mL

11.0 SUMMARY/CONCLUSION

This study was designed to answer the following questions:

- What are the characteristics of the water bodies receiving effluent from the cities of Colusa, Willows, Live Oak, and Biggs?
    a. Water source, use and overall hydrology?
    b. Is the water body designed or modified to convey or hold agricultural drainage?
    c. Is water quality sufficient to attain the MUN beneficial use (what is background quality)?
    d. Are there spatial and temporal trends?
- Does the effluent from the POTWs impact downstream water quality?

The overall study areas within the Sacramento River Basin have been hydrologically modified with flow highly managed to support Ag operations. Seasonal rainfall and wetland drainage provide runoff through the systems during the winter months, but source water to the areas during the spring and summer are primarily diversions from the Sacramento and Feather Rivers, groundwater and return flows from the Ag operations and wetlands. The receiving waters evaluated are ephemeral and would be dry during the majority of the irrigation season without imported water supplies.

All diversions and water rights within the water bodies are for irrigation use. There are no permitted diversions for municipal or domestic use and throughout the 18-month sampling period, there was no evidence of water being diverted for municipal or domestic supply. Central Valley Water Board staff met with Irrigation/Reclamation Districts and all have stated that they have never permitted any water diversion for municipal use.

The districts currently maintaining and operating the water bodies in question have construction records that identify water bodies built for Ag purposes and the date of construction. Based on the district records, all receiving water bodies were either specifically constructed or modified to convey Ag drainage to facilitate Ag operations throughout the basin.

When analyzing the water quality results collected from the four study areas against 144 criteria to protect MUN and/or human health, most constituents were below the evaluation criteria and for those that were above the criteria, some elevated concentrations occurred in the effluent but the majority occurred upstream and/or downstream of where the effluent might influence water quality. When elevated concentrations did occur in the effluent and not the background, the concentrations would dissipate as the water moved downstream.

Total aluminum, total iron, manganese, and sodium appear to be elevated in all background locations. Total and dissolved arsenic appear to be elevated in the southern portion of the study area and occurred most frequently in areas where groundwater was part of the water source. Trihalomethanes were rarely detected in any of the background sites with chloroform detected twice upstream of the effluent in the northern portion of the study area. E. coli concentrations randomly exceeded criteria both upstream and downstream of the influence from the cities' effluents.

Elevated concentrations of these constituents did not appear to be closely correlated with seasonal patterns except for E. coli which demonstrated elevated concentrations after the first storms of the season and also during the spring and summer months. Otherwise, elevated concentrations were more random with nitrate as nitrogen, ammonia, and *E. coli* correlated to low flow and no rainfall on the east side; SC, arsenic, and trihalomethanes correlated to low flow and no rainfall on the west side; arsenic from the east side and nitrate as nitrogen from the west side correlated to high flow and rainfall. Ammonia as nitrogen; and trihalomethanes on the west side with higher concentrations in spring/summer months than winter months.

Effluent of all four POTWs was consistently elevated in sodium, TDS, SC, and nitrate as nitrogen except that Biggs had ammonia as nitrogen because nitrification technology was not used. Specific conductance, nitrate as nitrogen, arsenic (total and dissolved), ammonia as nitrogen, and *E. coli* (Biggs effluent) had elevated concentrations in the effluent on the east side of the basin, whereas only SC, nitrate as nitrogen, and trihalomethanes were elevated in the effluent on the west side. Elevated concentration levels in the effluent usually impacted the first, immediate downstream site and was negligible further downstream. Willows effluent consistently reported elevated levels of chloroform, bromodichloromethane, and dibromochloromethane. The concentrations were not detected at any other north side site except for one sample collected upstream of the Live Oak that reported elevated levels of chloroform.

When reviewing the overall water quality throughout the basin, several constituents were reported at concentrations that exceeded criteria developed to protect municipal and domestic water supplies and human health. The elevated concentrations occurred both in effluent from the cities of Biggs, Live Oak, Willows and Colusa, as well as at sites both upstream and downstream of the effluents' influences. Constituents that are elevated in the effluent commonly dissipate after the first downstream site measurement. Constituents with elevated levels not related to the effluent appear to be linked to elevated levels in local ground water areas (e.g. arsenic) while others such as aluminum, iron, and manganese have correlate to historical background concentrations of metals in the surface waters of the Sacramento River Basin. Flows from these reservoirs are diverted through the basin as irrigation supplies. Due to the extensive hydrologic modification throughout the basin to maximize Ag production, fluctuating flow levels and recirculation of tail water to maximize water use efficiency, there are no readily apparent seasonal trends for the various constituents.

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